OBSERVATIONS MADE DURING TOTAL SOLAR ECLIPSES,

COLLATED BY

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PREFACE.

THE Astronomer Royal, in laying his report on the general proceedings of the Himalaya Expedition before the Royal Astronomical Society in 1860, remarked that—"In a subject where much of the value "of the observations will depend on the comparison of different persons' "observations, it may not improbably be found advantageous to break "up each account, and to collect from all the different accounts, first "those facts which relate to one part of the phenomena, and which will "aptly form one large chapter; secondly, those which relate to another "part of the phenomena, and which will form a second chapter, and "so on."

With the view of making a systematic comparison of observations such as he had suggested, the Astronomer Royal collected all the manuscript and printed accounts of the observations of the total eclipse of July 1860 which he could procure. But his continuous duties as Director of the Royal Observatory prevented him from carrying his idea into execution; and in 1871, after the return of the 1870 Eclipse Expedition, he proposed that I should assist him in carrying out his plan, and should embody the observations of the Eclipse of December 1870 with the unpublished observations he had collected of the Eclipse of July 1860.

With this object I commenced abstracting and arranging the observations of the eclipses of 1860 and 1870 under various headings, and gradually enlarged the plan of the work, so as to include observations made during other eclipses, as the advantages of bringing together all the

observations which I could collect with respect to doubtful or varying phenomena became apparent. No attempt has been made to collate observations of the Eclipse of July 1878, but up to that date references are given to all the more important physical observations I have been able to collect. It will probably be found that many observations have been overlooked: I shall therefore feel obliged to readers who will inform me of the omissions they may notice, and I would suggest that if possible a copy of any such unnoticed observations should be sent to be deposited in the Library of the Royal Astronomical Society.

My thanks are due to the Astronomer Royal for many valuable suggestions. I must especially refer to the important suggestion that all the drawings of the corona should be oriented with the sun's axis vertical upon the page; which has greatly facilitated the comparison of coronal drawings, and has brought out in a striking manner the general symmetry of the coronas which have been observed, with respect to the sun's axis.

To LORD LINDSAY I am indebted for the loan of measuring apparatus and the use of his laboratory and a lime light, whilst cataloguing the details visible upon the 1871 corona photographs, as well as for the loan of books and other assistance.

To MR. WESLEY I am especially indebted for the conscientious care he has bestowed upon the preparation of the illustrations in the volume, and for his assistance in cataloguing the details visible in the 1871 corona photographs—a work which occupied us more than a year.

To MR. MARTH I am indebted for checking nearly all the orientations and the statements involving calculations made in the volume. I am also indebted for the loan of books, manuscripts, and photographs to Padre SECCHI, Prof. ARGELANDER, Dr. SCHELLEN, Prof. YOUNG, Prof. WINLOCK, and others.

A. C. RANYARD.

Nov., 1879.

CONTENTS.

CHAPTER I.

OBSERVATIONS OF THE OCCULTATION OF SUN SPOTS BY THE LIMB OF THE MOON.

ATTENTION has been paid to the occultation of sun spots for the purpose of determining whether any alteration such as might be produced by the intervention of a lunar atmosphere could be perceived; but DAWES in 1836, ARAGO in 1842, DAWES more carefully in 1858, ROTTENBERG, SECCHI, DAWES, DEMBOWSKI and BURZETTI, in 1860, OFFICERS OF THE FRENCH NAVY in 1861, PRINCE and BRETT in 1870, have been unable to perceive any distortion. Under the head of negative evidence, see also observations of the sun's spectrum close to the moon's limb contained in the spectroscopic reports * of YOUNG, 1869, and STONE, 1874, where the slit was so placed that the image of the solar crescent fell upon one part of it, and the image of the dark moon upon the other; but no difference was detected in the Fraunhofer lines, at the place where they were seen to be sharply cut off by the limb of the moon.

LIAIS, in 1858, thought he saw the penumbra of one of the larger spots flattened out parallel to the moon's limb just before it was occulted, and he again observed a similar slight distortion on its reappearance. SCHOTT, in 1869, saw a black ligament form and re-form as the spots approached the advancing limb of the moon.

THE EMPEROR OF BRAZIL, in 1858, observed a yellowish tinge spread over the spots as the moon's limb approached them; and TALMAGE, in 1861, describes one of the spots as suddenly blazing forth with a mauve tint round it.

DAWES, in 1836, saw the black nucleus of one of the spots "considerably illuminated close to the moon's limb," but in 1858, after a

* Given in the chapter upon "The Band or Fringe along the Moon's Limb," p. 10.

"careful scrutiny," he came to the conclusion that "in no instance was either a bright or a dark object affected by the vicinity or contact of the moon's edge." ROTTENBERG, in 1860, observed that the nucleus and penumbra of a large spot appeared to grow fainter as they were occulted; and SECCHI, in 1860, found the penumbra of a spot grow hazy at the moment of its occultation. The explanation of these latter observations may possibly be connected with the phenomenon described in the next chapter—the sense of contrast between the colour of the spots and the blackness of the moon's disc not being perceived until they were in absolute contact.

Rev. W. R. Dawes.

ORMSKIRK,
15th May, 1836.

"Monthly Notices of the Royal Astronomical Society," Vol. iv., p. 24.

On the moon's edge passing over the largest of the solar spots visible on the day of the eclipse, a phenomenon was distinctly noticed, which was not observed during the occultation of any of the smaller ones. The black nucleus appeared considerably illuminated close to the moon's limb.

No distortion of the edges of the spot was noticed by any of the observers.

M. Arago.

PERPIGNAN,
8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 351.

lo distortion or lteration in intensity observed.

Nous ne parvînmes pas, mes collaborateurs et moi, à saisir la moindre trace d'une atmosphère lunaire. M. Eugène Bouvard, à Digne, ne fut pas plus heureux. Aucune des facules qu'il vit s'enfoncer sous le disque obscur de la Lune ou reparaître, ne sembla altérée ni dans sa forme ni dans son intensité.

Rev. W. R. Dawes.

HADDENHAM, NEAR THAME,
15th March, 1858.

"Monthly Notices," Vol. xviii., p. 188.

I employed an excellent 7½-inch object-glass recently received from Mr. Alvan Clark. The steadiness and distinctness of the image induced me to pay especial attention to the appearance of well-marked *pores*, and small bright spots, or *loculi*, on the sun's surface, as the moon approached and occulted them. Keeping my eye steadily upon them, I was able, in numerous instances, to note whether the edge of the moon produced any dimness or distortion or change of place as it touched and passed over them. The same close attention was bestowed upon the best-defined portions of the extremely delicate network connected with the magnificent mass of solar spots; which was just completely occulted by the moon when the clouds thickened, and the sun was seen no more till after the eclipse terminated.

The result of this careful scrutiny was, that in no instance was either a bright or a dark object affected by the vicinity or contact of the moon's edge previously to its occultation. No dark shade adhering to its edge was seen on the bright parts, nor was any bright line visible on the dark parts, as they successively disappeared. No distortion, or tremour, or projection, was perceived in any of the numerous objects thus examined during the fifty minutes of visibility.

Dr. Liais.

PARANAGUÁ,
7th Sept., 1858.

"Astr. Nachr.," Vol. xlix., p. 278.

Apparent alteration in form of spots as they were eclipsed by the moon's limb.

A la station centrale de Paranaguá M. LIAIS a noté que le bord de la lune s'est trouvé en contact avec le bord de la pénombre du 3^me^ groupe de taches solaires, celui qui était le plus près du centre de l'astre, à 10 h. 13 m. 32 s., achevant aussi de recouvrir cette pénombre. Il a de plus remarqué qu'à mesure que le bord de la lune recouvrait la pénombre, cette dernière semblait près de l'instant du contact, éprouver une petite variation de forme, son bord paraissant s'aplatir parallèlement au bord de la lune. Une apparence semblable s'est produite dans la seconde partie de l'éclipse à la réapparition des taches. Cette observation a été faite avec un grossissement de 300 fois.

M. Coilho. PARANAGUÁ, 7th Sept., 1858.

"Astr. Nachr.," Vol. xlix., p. 278.

No variation in intensity of sun spots observed at the moment of their occultation.

M. COILHO a noté qu'au moment où le bord de la lune allait occulter les taches, ces dernières n'ont paru éprouver aucune variation d'intensité comme cela aurait eu lieu s'il s'était produit l'interposition d'une atmosphère lunaire.

The Emperor of Brazil. PALACE OF ST. CHRISTOPHER, 7th Sept., 1858.

"Astr. Nachr.," Vol. xlix., p. 278.

Yellowish tinge seen to overspread sun spots just before occultation.

Il a été également remarqué au Palais Impérial de St. Christophe, en regardant le soleil dans une lunette puissante avec une verre vert que, quand la lune a approché de la grande tache et de la suivante, on a cru voir se répandre sur elles une couleur jaunâtre. Cette couleur a semblé se disperser déjà sur le groupe des petites taches, quand déjà la lune couvrait la moitié de la grande tache.

Baron de Rottenberg. VALENCIA, 18th July, 1860.

MS. Observations of the Himalaya Expedition.

When the large spot was occulted the penumbra got very faint when the nucleus was hid; and the nucleus seemed to get fainter when about one-half of it was covered. I observed no distortion whatever of the form of the spot.

Padre Secchi. DESIERTO DE LAS PALMAS, 18th July, 1860.

"Relazione delle Osservazioni," etc.: P. Secchi, Rome, 1860.

No distortion of spots. Penumbra became slightly hazy.

Le macchi del sole non mostiarono veruna distorsione all' istante della loro occultazione, e solo trovai un poco di indecisione nell' occultazione della penombra, il che si deve alla lor naturale sfumatura.

The Rev. W. R. Dawes. HADDENHAM, BUCKS,
18th July, 1860.

"Monthly Notices," Vol. xxi., p. 26.

I employed my 8½-inch object-glass, with powers of from 145 to about 520. The most minute and delicate feathery portions of the penumbra of the large spot in the sun's north-western quadrant were thus brought out with admirable distinctness, and their occultation by the moon's sharply defined edge was thus carefully watched. Neither on these nor on the darker part (or *umbra*) of the spot was the slightest effect produced, either in form or shade, previous to their disappearance.

Baron Dembowski. MILAN,
M. Burzetti. 18th July, 1860.

"Astr. Nachr.," Vol. liii., p. 343.

Or malgré la plus grande attention possibles, ni M. BURZETTI, ni moi, nous n'avons pu rémarquer le moindre changement appréciable dans la forme des taches. No change noticed.

Officers of the French Navy. SAINT LOUIS, SENEGAL,
31st Dec., 1861.

"Monthly Notices," Vol. xxii., p. 168.

Aucune des taches en s'immergeant, ou en reparaissent, n'a subi la moindre altération de forme. No alteratio form.

Mr. C. G. Talmage. NICE,
31st Dec., 1861.

"Monthly Notices," Vol. xxii., p. 92.

At the total immersion of one of the spots, it seemed suddenly to blaze forth, and quite a mauve tint was visible round it.

Mr. Charles A. Schott. SPRINGFIELD, ILLINOIS,
7th Aug., 1869.

"United States Coast Survey Report" for 1869, Appendix viii., p. 36.

When the moon's limb had nearly touched the penumbra of the spot, a black band suddenly shot out from the umbra (of the same width), and for an instant was connected with the moon's limb; it then retreated and re-formed, making apparently a bridge across the penumbra; it was then gradually shortened and covered by the advancing moon. This connection was distinctly seen for several seconds, though each forming, retreating, and re-forming, was, perhaps, completed in half a second.

Mr. Prince. UCKFIELD, SUSSEX,
22nd Dec., 1870.

"Monthly Notices," Vol. xxx., p. 67.

I particularly noticed that the penumbra of each [of the spots] was well defined to the instant of occultation.

Mr. John Brett. AUGUSTA,
22nd Dec., 1870.

"Monthly Notices," Vol. xxxi., p. 164.

At Mr. Burton's suggestion I very carefully observed the eclipse of two large spots, with power 200 for distortion, but found no trace of any definition being then good.

CHAPTER II.

THE MOON SEEN TO BE DARKER THAN SUN SPOTS.

DURING the passage of the moon's limb over sun spots, a good opportunity is afforded of comparing the blackness or colour of the nucleus of the spots with that of the moon's disc. It should be remembered that during the partial phases of an eclipse the atmosphere between the observer and the sun is brilliantly illuminated, and, added to this, the moon is exposed to full or nearly full earthshine.* The moon nevertheless appears as a deep black compared with the darkest parts of the sun spots. MADLER, WEYER, HAASE, DEMBOWSKI and BURZETTI in 1860, and DANCER and PRINCE in 1870, describe the moon's disc as much blacker than the sun spots; while W. F. is alone in describing the moon and sun spots as "of so precisely the same tint" that they appeared "to be merged" in one another. LONGOMONTANUS's observation was made with one of the earliest telescopes,† and can hardly be compared with the above: to his eye the sun spots appeared darker than the moon.

The moon is described by

Weyer	as	deep black,
Haase	as	tief schwarz,
Dembowski, Burzetti	as	noir le plus parfait qu'on puisse imaginer,
Dancer	as	black,
Prince	as	intensely black.

* It will be seen from a future chapter that even during totality the illumination of the atmosphere over the moon's place is sufficient so completely to overpower the effects of earthshine upon the moon that the maria and other details are not distinguishable.

† Longomontanus's observation is described as being made "per tubum." As the eclipse took place only three years after the date usually assigned for the discovery of the telescope, it is probable that the optical means at his disposal were very inferior.

The spots are described by

Madler	as	grau,
Weyer	as	gray-black,
Haase	as	hell-braun,
Dembowski / **Burzetti**	as	brun foncé.

Longomontanus. 20th May, 1612.

"Historia Cœlestis," fol. 1666, Vol. II. Parlipomenos, p. 922.

Sun spots darker than moon.

Maculæ Solis tunc apparebant nigriores quam Luna.

Dr. J. H. von Madler. VICTORIA, 18th July, 1860.

"Ueber Totale Sonnenfinsternisse." DR. VON MADLER.

Sun spots gray as compared with the moon.

Die Bedeckung des Sonnenflecks, konnte ziemlich scharf beobachtet werden; und der Unterschied der Intensität zwischen Mond und Fleck war ein überaus grosser. Der vorhin schwarz erscheinender Fleck konnte kaum noch als Grau bezeichnet werden.

Prof. G. D. E. Weyer. VICTORIA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The deep black colour of the moon (as it passed across the solar disc) was in remarkable contrast to the lighter gray-black colour of the solar spots, even in their darkest parts.

Herr C. Haase. VALENCIA, 18th July, 1860.

"Astr. Nachr.," Vol. liv., p. 339.

Spots light-brown in comparison with black disc of moon.

Im Vergleich zu dem tief schwarz gefärbten Mondkörper erschien mir die Farbe der Kernflecken, die ich vorher ebenfalls fur schwarz gehalten, nur noch hellbraun.

Baron Dembowski. MILAN,
M. Burzetti. 18th July, 1860.

"Astr. Nachr.," Vol. liii., p. 343.

La seule chose que je remarquai, ce fut que les fonds des taches, qui éloignées du bord de la lune paraissait, devenait d'une couleur brun foncé, tandis que le disque de notre satellite était du noir le plus parfait qu'on puisse imaginer.

Spots on dark-brown moon as perfect a black as one can imagine.

W. F. EXETER, 22nd Dec., 1870.

"Nature," Vol. iii., p. 185.

A remarkable phase in the moon's passage across the sun was the perfect apparent contact of the limb of the moon with a sun spot. The noticeable thing was that the body of the moon itself and the sun spots were of so precisely the same tint that no trace of a division was perceptible,—one appearing to be merged in the other as long as the contact lasted.

Mr. J. B. Dancer. ARDWICK, NEAR MANCHESTER, 22nd Dec., 1870.

"Monthly Notices," Vol. xxxi., p. 68.

The black surface of the moon, when projected on the sun's disc, appeared very uniform in colour, and darker than any of the spots.

Mr. Prince. UCKFIELD, SUSSEX, 22nd Dec., 1870.

"Monthly Notices," Vol. xxxi., p. 67.

The moon appeared intensely black while passing over the sun's disc, and it was interesting to observe how much darker the limb was than either the umbra or the actual nucleus of any spot.

CHAPTER III.

BAND OR FRINGE ALONG MOON'S LIMB.

THIS chapter contains observations of fringes of colour and dark and bright bands which have been noticed by various observers along the part of the limb of the moon which is projected upon the sun's disc during the partial phases. It will be seen that the phenomena described cannot all be accounted for by supposing that the instruments used by the observers were not sufficiently corrected for colour; nor can they be explained as due merely to an effect of contrast between the light and dark discs of the sun and moon. In many instances the observers describe the fringes as growing in intensity, or springing into existence, at a certain time or period of the eclipse; but it does not appear with sufficient distinctness that they had given their attention to the same phenomenon before. None of the observers, except GILLISS in 1860, describe the fringes as disappearing or growing faint at a certain time.

The observations are not always described with sufficient distinctness to enable us to determine whether the fringes were seen upon the moon's disc or upon that of the sun; and when described as upon the sun, it is not always clear whether the observer means that the fringes were upon the sun's limb (that is, on the convex side of the crescent), or upon the part of the sun's disc adjacent to the moon's limb (the concave side of the crescent). If the coloured fringes were due to want of achromatism in the object-glass, we should expect to find the same outstanding fringe of colour on both the convex and concave sides of the crescent; but in no instance is this the case. If due to the eyepiece, we should expect, with a narrow crescent nearly filling the field, to find a red fringe on one side of the crescent and a blue fringe on the other side; but the fringe would be lost when brought to the centre of the field. First, as to those observers who describe bands or fringes without specially noting them as coloured.

Upon the sun's disc :—

1836.	**Coulier.**	Several shadowy circles preceding the lunar limb.
1858.	**Paroissien.**	Band surrounding moon's limb.
	Stuart.	Three faint bands or fringes evidently on the sun's disc from the description of the lunar mountain.
1860.	**Venables.**	Portion of sun around moon's edge brighter.
	Murray.	Light whitish ring, broader after totality.

Upon the moon's disc :—

1870.	**Weston.**	Disc of moon enlightened for some distance from its periphery.
	Brett.	Weak illumination encroaching upon moon.

Upon the discs of both sun and moon :—

1851.	**Aidie.**	Narrow sharp band round the part of moon's disc projected on sun; within this a portion of body of moon illuminated.

On the other hand, LANE in 1854 says he made it his chief business to look for the fringe of light which observers had noticed along the moon's limb, but saw none when the eye was kept fixed, though with the eye in motion a coloured border was often very vivid. VENABLE in 1860 could see no fringe when looking through his telescope, though he saw one with the naked eye; and HARKNESS and TUPMAN in 1870 could not make sure of the existence of such a fringe.

Observers who describe coloured fringes :—

1851.	**Busch.**	Orange-red fringe on moon; violet light on sun's limb.
	Fearnley.	Orange fringe on moon, and a corresponding light-blue on the other side (*query* of crescent).
1857.	**Clarke.**	Blue edge outside; red light along inner edge of sun's lower limb.
1860.	**Gilliss.**	Violet or reddish-blue fringe.
	Smith.	Before totality a narrow band of deep yellow; after totality blue band made up of radiations perpendicular to limb on moon, and yellow band (*query* on sun).
1861.	**Hardy.**	On moon band of deep purple; on sun brighter band, separated from the moon's edge by pale-green shadow.
	Talmage.	On moon streak of red light.
1867.	**Weiss.**	Yellow faint light on moon.
1869.	**Hough.**	Red band on sun.

Many of the observers mention a definite time at which they observed the fringes,—leaving it to be inferred that no fringe was visible before that time; and BUSCH states definitely that the fringes became visible at a certain time, and that they were not visible before.

1851.	Aidie.	At 3h. 35m.
	Busch.	About 3h. 37m., light on moon; 10 or 15 seconds later, fringe on sun. Before this the moon's limb had appeared black.
1858.	Paroissien.	When a considerable portion of the sun had reappeared, I observed. . . .
	Stuart.	Ten minutes after the commencement of the eclipse.
1860.	Gilliss	Says that the fringe *disappeared* gradually, after the moon's limb had passed the sun's centre.
1861.	Hardy.	Soon after the eclipse began, and for some time afterwards.
	Talmage.	At 3h. 45m.
1869.	Hough.	When the sun was about half eclipsed.
1870.	Harkness.	At 12h. 8m. I fancied I saw a very faint and narrow bright line.

Though the fringes are usually described as lying symmetrically along the whole length of the part of the moon's limb seen projected upon the sun, yet in some instances this is not the case.

1851.	Busch.	Colour on moon concentric with limb. Colour on sun crescent-shaped, and not reaching as far as the sun's cusps.
1857.	Clark.	Red light along the inner edge of the sun's lower limb.
1861.	Talmage.	Semicircular streak on moon, gradually diminishing to two abrupt points.
1867.	Weiss.	Faint yellow light, most distinct near protuberance.

M. Coulier. (No place given),
15th May, 1836.

"Comptes Rendus," Tome ii., p. 497.

Several shadowy circles preceding the lunar limb.

M. Coulier parle dans sa lettre de plusieurs cercles ombrés qui précédaient le corps de la Lune, et qu'il est disposé à attribuer à l'atmosphère lunaire.

Mr. John Aidie. GÖTHA KELLARE HOTEL, GÖTTENBURG,
28th July, 1851.

"Monthly Notices," Vol. xii., p. 63.

At 3h. 35m. Göttenburg M.T., the moon appeared to have a narrow sharp band, intensely black, round the whole portion of her disc seen projected on the sun; while within this black band, a portion of the body of the moon appeared illuminated, and of a greyish white colour.

Dr. Busch. RIXHÖFT, 28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 231.

Nachdem ich einige Notizen aufgeschrieben und darauf wieder in das Fernrohr sah, bemerkte ich, etwa um 3h. 37m., dass der noch kurz vorher schwarz erscheinende Mondrand mit einem Saume von orangerother Farbe umgeben war, und dass etwa 10 bis 15 Sekunden später, der bis dahin ebenfalls farblos gewesene Sonnenrand einen Anflug von Violett annahm. Dieses violette Licht wurde nach und nach am Sonnenrande immer dunkler und verbreitete sich, in den feinsten Abstufungen, bis zur Mitte der Sonnensichel, wo es dann in ganz schwaches Gelb überging. Der farbige schmale Ring um den sichtbaren Mondrand war mit der Mondscheibe concentrisch, dagegen erschien das violette Licht sichelförmig ohne sich bis zu den Hörnerspitzen der Sonnensichel auszudehnen.

Orange-red fringe along moon's limb. Violet light on sun's limb. Broadest near cusps (query).

Prof. Fearnley. RIXHÖFT, 28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 237.

Von den gefärbten Rändern der Sichel, die Director Busch mit besonderer Aufmerksamkeit beobachtet hat, kann ich nur soviel sagen, dass allerdings ein feiner, aber intensiver orangefarbiger Saum am Mondrande und ein entsprechender hellblauer auf der anderen Seite mir mehrmals bei der schon kleinen Sichel aufgefallen ist.

Orange fringe along the moon limb and corresponding light blue on other side.

Mr. J. Homer Lane. WASHINGTON, 26th May, 1854.

"United States Coast Survey Report" for 1869, Appendix No. 8, p. 59.

I made it my chief business during the continuance of the eclipse to look for the fringe of light which has sometimes been reported as seen along the moon's limb projected on the sun's disc; I saw nothing of the kind except what was distinctly traced at the time to the eye itself. I experimented on this point all through the time of the eclipse. Whenever the eye was held for some little length of time without a wink, and in complete fixity upon the object, all distinctively border-light invariably disappeared, leaving nothing but purely the projection of the moon's form

upon the sun. But not the slightest movement or change in the eye could take place, with this point on the attention, without calling into instant being a coloured border, often very vivid.

The Rev. W. B. Clarke. SYDNEY, 26th March, 1857.

"Monthly Notices," Vol. xviii., p. 41.

Mr. C. Martens, of St. Leonard's, very ingeniously threw an image of the eclipse through his inverting telescope upon a white screen, and saw a *blue* edge *outside* the indentations of the moon's disc, and a bright *red* light along the *inner* edge of the sun's lower limb.

Rev. Challis Paroissien. HARDINGHAM, NORFOLK, 15th March, 1858.

"Monthly Notices," Vol. xviii., p. 249.

When a considerable portion of the sun had reappeared I observed distinctly a circular band, ... surrounding the portion of the moon's dark limb that was projected on the solar disc. . . . . The space included between this circle and the dark edge was the slightest possible shade darker than the sun's disc.

Mr. C. Stuart. IPSWICH, 15th March, 1858.

"Monthly Notices," Vol. xviii., p. 194.

[Ten minutes after the commencement of the eclipse.] The light from the sun was very distinctly seen within the edges, and slightly illuminating the dark body of the moon for a short distance, and had the appearance at its termination of three faint bands or fringes of light parallel with the edge of the moon. . . . It was in the light passing inwards along the convex surface of the moon that the before-mentioned lunar mountain was situated; it did not appear to me to be directly on the edge, but a little inside of it, yet still high enough for the top to be beyond the edge, and appear in dark relief upon the sun's disc.

Lieut. J. M. Gilliss. STEILACOON, WASHINGTON TERRITORY, 18th July, 1860.

"Coast Survey Reports," 1860; Appendix No. 22.

Instrument.—A comet-seeker, made by Merz and Mahler of Munich, $3\frac{9}{10}$ in. clear aperture and 34·6 in. focal length. The eyepiece magnified thirty-two times, and was fitted with a series of differently-tinted screen glasses.

(p. 13.) [During the partial phases after totality] I observed that closely around the following limb as it passed over the sun, and until it was beyond the centre of the latter, was a delicate violet or reddish-blue fringe, which made it difficult to detect the exact instant at which the solar spots emerged. The fringe disappeared gradually.

Prof. A. W. Smith. AULEZAVIK ISLAND, 18th July, 1860.

"Coast Survey Reports," 1860; Appendix No. 21.

Instrument.—A telescope made by Plössl of Vienna, with an object-glass of about 3 in. aperture and 38 in. focal length.

(p. 26.) A bright but narrow band of deep yellow was seen soon after the moon's limb entered upon the sun's disc, and was visible, or was seen, till the moon approached the large dark spot on the sun. It may have continued longer visible, but my attention was not subsequently directed to it. This was not the effect of chromatic aberration, as the whole band was made to pass near the centre of the field, and was separated from the white light of the sun by a distinctly-seen dark line.

[After totality] a blue band of considerable breadth surrounded that portion of the moon which covered the sun. This band appeared to be made of radiations of blue light of different degrees of intensity in a direction perpendicular to the sun's surface. It was bounded by a well-defined line on the moon's surface. I was instantly reminded of the "mirage" so frequently witnessed on our voyage to this place, in which the horizon appeared to be skirted by a blue sea-wall. The resemblance to an unbroken sheet of water (varying in thickness or irregular in surface, so as to vary the shading) falling over a mill-dam also occurred to me. At the base, where it was in contact with the sun, was a very narrow band or line of yellow as noted before totality.

(p. 25.) I decided to use a low power which would bring the whole disc of the sun into the field at once. I found, however, while observing the eclipse, a perceptible want of achromatism on the borders of the field. The screen used gave a white image of the sun.

Prof. C. S. Venables. AULEZAVIK ISLAND,
18th July, 1860.

"Coast Survey Reports," 1860; Appendix No. 21, p. 27.

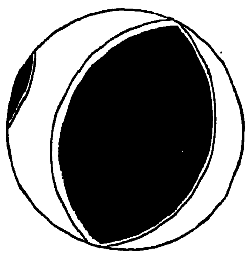
Several times during the partial phases I thought the portion of the sun around the moon's edge brighter than the rest, but could not with my telescope distinguish it as a bright band around the moon's edge.

Mr. E. W. Murray. LLOLIO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

Before the totality I could see plainly the light whitish ring—being in width, as far as I could judge, about $\frac{1}{10}$th the diameter of the moon. It was from this ring that the corona sprang: it skirted the hinder part of the moon, though as yet no rays shot forth from it.

Also when the totality was over, and the moon had passed over perhaps



a quarter of the sun in its retreat, I observed what I supposed to be the same ring,—very much smaller than the ring during the totality; but nearly double the size of the ring which I observed on the advancing edge. I have marked them both in the figure. When a black surface passes over a shining one, there generally appears a lighter-coloured ring at the edge of the black surface: but why the difference in widths, with the advancing and retreating moon, when almost the same surface of sun was exposed?

Mr. R. W. H. Hardy. SION HILL, BATH, 31st Dec., 1861.

"Monthly Notices," Vol. xxii., p. 90.

Soon after the eclipse began, and for some time afterwards, the overlapping surface of the moon was covered over with a soft grey tint, which terminated on the advancing edge in a narrow band of deep purple. Concurrently with this purple band there appeared, in advance of the moon's edge, but concentric with it, at a short distance, a bright gleam of light, brighter than the solar disc. This light was separated from the moon's edge by a narrow pale-green shadow, which softened into the former. . . .

My telescope is a 12-inch Newtonian reflector; the eyepiece I used on the occasion was an inverting one, and the power employed, sixty times,—which takes all the sun into the field. The projecting glass was a neutral tint, which does not materially affect the appearance of the colour of natural objects.

Mr. Talmage. NICE, 31st Dec., 1861.

"Monthly Notices," Vol. xxii., p. 92.

At 3 h. 45 m., a remarkable phenomenon presented itself on the surface of the moon: there appeared a semicircular streak of red light close to the limb, gradually diminshing to two abrupt points.

Dr. Ed. Weiss. RAGUSA, 6th March, 1867.

Vol. lv. of the Sitzb. d. k. Akad. d. Wissensch, ii. Abth., May, 1867.

(p. 17.) Endlich zeigte sich innerhalb des Mondrandes ein gelblicher, Schimmer der in der Gegend der Protuberanz,* am deutlichsten auftrat.

Yellow light inside the moon's limb—brightest near protuberance.

Prof. G. W. Hough. MATTOON, ILLINOIS, 7th Aug., 1869.

"Journal of the Franklin Institute," Jan. 1870, p. 61.

When the sun was about half eclipsed, a red band of light was seen surrounding the limb of the moon over the solar disc.

* This was long before the period of greatest obscuration. The eclipse was annular.

Mr. Charles H. Weston. LANSDOWN, NEAR BATH, 22nd Dec., 1870.

"Monthly Notices," Vol. xxxi., p. 70.

The disc of the moon overlapping the sun was *not uniformly dark, but enlightened for some distance from its periphery coextensively with the arc of contact.*

Mr. John Brett. AUGUSTA, 22nd Dec., 1870.

"Monthly Notices," Vol. xxxi., p. 164.

There was a weak illumination encroaching upon the moon, of a greyish tint; but it faded away from the limb inwards imperceptibly.

Prof. Harkness. SYRACUSE, 22nd Dec., 1870.

"Washington Observations," 1869, Appendix I., p. 79.

As the eclipse advanced, I looked very carefully for the bright line which was shown in such a marked manner along the edge of the moon's limb in the photographs taken by Dr. Curtis, at Des Moines, in August 1869; but, although I used both red and neutral tint shade-glasses, and the definition in the telescope was excellent, I could not see any trace of it till 12 h. 8 m., when I fancied I saw a very faint and narrow bright line; but I am far from being certain that such a line really existed. In fact, I am inclined to think it was only the effect of contrast between the bright sun and the dark moon.

Capt. Tupman. SYRACUSE, 22nd Dec., 1870.

"Washington Observations," 1870, Appendix I., p. 118.

During the partial phase we looked for a line of brighter light on the sun parallel to the limb of the moon. I once or twice fancied something of the kind, but the immediate contrast would account for it. I think it was with a power of eighty or ninety, with fair definition.

CHAPTER IV.

ON THE SPECTROSCOPIC AND PHOTOGRAPHIC EVIDENCE OF A FRINGE ALONG THE MOON'S LIMB.

Spectroscopic.

Young in 1869, and Stone in 1874, both examined the solar spectrum in the neighbourhood of the moon's limb, but neither of them were able to detect any additional lines, or change in the appearance of the ordinary Fraünhofer lines where they were cut off by the moon's limb.

Prof. C. A. Young, Burlington, Iowa, 9th Aug., 1869.

"The American Journal of Science and Arts" for November 1869, Vol. xlviii., No. 144, pp. 374-5.

Instrument.—A 4-inch telescope, with eyepiece, giving an image of the sun $2\frac{1}{8}$ inches in diameter, and spectroscope with slit $\frac{1}{8}$th of an inch long, and five prisms of 45°.

While the moon was advancing upon the sun, special attention was paid to the appearance of the spectrum lines near her limb. They came up to the edge perfectly square and straight, even when the limb made an angle of only 5° or 6° with the slit; and the longitudinal line of demarcation between the two portions of the spectrum was hard and sharp, in striking contrast with the effect of the sun's limb, which, under similar circumstances, always gives a boundary more or less hazy and indefinite, and this to a degree continually changing from minute to minute. This contrast was beautifully exhibited a few seconds before totality, when the limbs of both sun and moon were on the spectrum together, the width of the visible portion of the sun having become less than the length of the slit. It was at first thought that this appearance was decisive against the

existence of a lunar atmosphere, however rare; but a little consideration shows that, on the other hand, it is, if anything, favourable; being a simple consequence of that brightening of the sun's disc near the moon's limb, which is so beautifully evident upon the photographs; and which is most easily accounted for by admitting a slight refraction suffered by that portion of the sunlight which grazes the moon. Possibly, however, it may yet be explained as a case of simple inflection of light.

Mr. Stone, KLIPFONTEIN,
16th April, 1874.

"Memoirs of the Royal Astronomical Society," Vol. xlii., p. 43.

With respect to the existence of additional absorption lines in the sun's spectrum near the moon's limb, I examined this point with considerable care during the partial phase, but I could not detect the presence of any additional lines, nor any sensible change in the appearance of any of the Fraünhofer lines in the spectrum near the moon's limb from that presented at considerable distances from it.

Photographic.

Reference has frequently been made to a band of increased brightness along the moon's limb in the partial-phase photographs. Professor Stephen ALEXANDER, in his account of the observations of the eclipse of 1860, published in the "Reports of the United States Coast Survey," (Appendix 21 to Report for 1860, p. 13), says that the bright band which he had observed through the telescope "is unquestionably pictured in the copies of daguerreotypes of the eclipsed sun, taken at Mr. Campbell's observatory in New York, under the supervision of Mr. Campbell and Professor Loomis, in May, 1854.

Mr. DE LA RUE, in his Bakerian Lecture on the eclipse of 1860,* says: "Photographs of the various phases of the partial eclipse, either previous to or after totality, exhibit a very curious phenomenon. The concave edge of the sun in immediate contiguity with the moon's limb, appears brighter than the other neighbouring parts of the crescent, while

* Published in the "Philosophical Transactions" for 1862, part i., p. 36.

the convex limb of the sun bordered by the dark background of the sky does not appear at all brighter than its proximate parts. This brightening of that part of the sun's disc which borders on the moon's limb extends only for the space of a narrow line beyond the latter, but is remarkably conspicuous." The Astronomer Royal, to whom Mr. De la Rue had pointed out the fact, ascribed it to an effect of contrast. And Mr. De la Rue, after describing certain experiments which he had made, expressed himself as of the same opinion.

Professor CHALLIS, in a paper entitled "On the Indications by Phenomena of Atmospheres to the Sun, Moon, and Planets," published in the "Monthly Notices," vol. xxiii., pp. 231-8, adduces the existence of the bright band upon the photographs in proof of a lunar atmosphere of extreme rarity.

The ASTRONOMER ROYAL, in a paper in the "Monthly Notices," vol. xxiv., pp. 13-19, "on the origin of the apparent luminous band which, in partial eclipses of the sun, has been seen to surround the visible portion of the moon's limb," shows by a theoretical investigation of the optical conditions, that refraction by a lunar atmosphere cannot cause apparent increase in brightness of the parts of the sun's disc adjacent to the place of the moon's limb. At page 188 of the same volume of the "Monthly Notices," the Astronomer Royal describes certain experiments which he had made, with specimens of partial-eclipse photographs which had been sent to him by Professor Stephen Alexander; and concludes that the phenomenon is due to nervous irritation of the retina, produced by the view of the conterminous black and white portions of the photograph.*

Professor MORTON, in the "Journal of the Franklin Institute," Sept. 1869, p. 209, says that the partial-phase photographs taken at Mount Pleasant in August, 1869, "all show an increase of light on the solar surface where it is in contact with the edge of the moon." He thinks that this is clearly not a subjective effect, but is due "to an increased deposit of silver" in the neighbourhood of the line of division between the light and dark parts of the picture.

* See also "Monthly Notices," vol. xxiv., p. 49; vol. xxv., p. 18; and paper by Professor Pickering in the "Journal of the Franklin Institute," April 1870, vol. lix., p. 264; "Comptes Rendus," vol. lxix., pp. 1234-6; "Journal of the Franklin Institute" for Dec. 1869, p. 374; "Philosophical Transactions," 1862, p. 368.

Dr. Curtis also noticed a similar band of increased brightness along the moon's limb in the partial-phase photographs taken at Des Moines in 1869, and after repeating experiments similar to those described by Mr. De la Rue, he came to the conclusion that the appearance was not due to a sense of contrast. He therefore commenced experiments upon photographs of an artificial eclipse which he describes in the "Washington Observations" for 1870, Appendix II., p. 137.

He first photographed a circular disc of ground-glass, brightly illuminated from the back, with a piece of black paper pasted on it to represent the moon; but the negative did not show "the slightest trace of a bright border to the line of the dark disc." He then placed the artificial moon some inches in front of the illuminated disc, brought the limb of the artificial moon into sharp focus, and obtained a negative with a very marked bright border along the edge of the dark moon. To make sure that the appearance was not due to contrast, he placed beneath one of the negatives thus taken a piece of paper, on which was a line of printed dots. On holding the negative to the light, the dots could be plainly seen through the centre of the image of the ground-glass representing the sun; but close to the edge of the artificial moon they disappeared, nor could any amount of straining of the eyes make them visible; showing that for a narrow space bordering this edge the deposit in the negative was actually denser than on the rest of the image of the sun.

time as the clouds passed on, he again saw both the sun and a portion of the moon's border *which was off the sun's disc.* The sky then became cloudless, and he could no longer discern any part of the moon's limb, except that which eclipsed the sun.

Mr. Dunkin. CHRISTIANIA, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., part i., p. 12.

As the totality approached, I examined the moon's limb; but could not see it beyond the sun's limb.

Mr. J. W. Good. KROPP, 28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 150.

I did not see the moon's circumference outside the sun's disc during the partial eclipse, either during the increase or decrease.

Rev. W. R. Dawes. REVELSBERG, near ENGELHOLM, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., part i., p. 87.

No illumination of the moon's limb was ever perceived. At one time I thought there was some appearance of its outline just off the northern portion of the sun's disc, but on altering the position of the objects in the field, the appearance also varied; proving that it arose from some reflexion of the sun's light from one of the eye-glasses. The sun was at that time in the field; but when it was excluded no such appearance presented itself.

Mr. Humphreys. CHRISTIANSTADT, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xvi., part i., p. 18.

No portion of the moon external to the sun's limb could be seen before the totality.

Baron Dembowski. CREMANO, near NAPLES, 28th July, 1851.

"Astr. Nachr," Vol. xxxiii., p. 201.

Twenty minutes before the maximum obscuration the moon's limb was seen for a distance of 3' outside sun. Similarly 20 m. after the maximum observation.

Circa 20 m. prima della massima oscurazione, vide che il lembo orientale della luna per la lunghezża di 5° in 6° a partire dal como luminoso (ossia dal punto d' incontro delle circonferenze di due dischi) era circondato da una porzione di fascia di un colore per lo meno più chiaro del disco lunare, e del campo oscuro del telescopio della larghezza di circa 3′, più larga e distinta, cominciando dal corno luminosa e sfumantesi a poco a poco, sembrandogli che fosse concentrica al disco del sole . . . . Il disco solare era apparentemente affatto privo di una simile fascia. Su questa porzione di fascia od aureola gli parve di bene discernere il contorno del nostro satellite. Tale fenomeno si riprodusse al lembo opposto e nello stesso intervallo di tempo, colla differenza che secondo che la porzione d' aureola occidentale guadagnava in intensita quella orientale diminuiva, finchè circa 20 m. dopo la massima oscurazione, il tutto era svanito. La vista di questa porzione di aureola gli parve non fosse una semplice illusione, massime nel mezzo dell' ecclisse in cui esisteva da ambe le parti del disco lunare.

Professor Olufsen. CALMAR, 28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 219.

Moon's limb not seen.

Ebenso wenig habe ich den Rand des Mondes ausserhalb der Sonne gewahr werden können.

M. Goujon. DANTZIG, 28th July, 1851.

"Comptes Rendus," Vol. xxxiii., p. 180.

Moon's limb not seen outside the sun's disc before totality—visible only for 87 sec. after totality.

Avant le commencement de l'éclipse totale, j'ai cherché en vain à apercevoir la partie du limbe de la lune qui ne se projetait pas sur le soleil, même en ayant soin de mettre ce dernier astre en dehors du champ de la lunette. A 4h. 35m. 9s., ou 33 secondes environ après la fin de l'éclipse totale, j'ai vu très nettement le contour entier de la lune, il était surtout visible près de la périphérie du soleil. Je ne le distinguai plus au bout de quelques secondes; mais, sur l'invitation de M. Mauvais, ayant ôté le verre noir faible dont je me servais alors, je l'ai encore aperçu. Tout a disparu à 4h. 36m. 6s.

Dr. Julius Schmidt. RASTENBURG,
28th July, 1851.

"Beobachtung der Totalen Sonnenfinsterniss zu Rastenburg:" Bonn, 1852.

Moon's limb carefully lool for, but not s

(p. 4.) Vordem Anfange der Totalität habe ich nie eine Spur des Mondrandes ausserhalb der Sonne erkennen können, obgleich ich sehr darauf Acht gab, selbst dann nicht, wenn ich die Sonne aus dem Gesichtsfelde entfernte, und in dieser Lage das dunkle Augenglas zurückzog.

Mr. W. Simms, Jun. 138, FLEET STREET, LONDON,
15th March, 1858.

"Monthly Notices," Vol. xviii., p. 189.

When the eclipse had pretty far advanced, probably about a fifth of the sun's diameter being covered, a thin cloud or haze spread itself over the sky, and an exceedingly light neutral tint shade was sufficient. I then distinctly saw the moon's edge for a distance of about five minutes beyond the sun's limb, the moon's surface being also of a different shade from the sky beyond, reminding me of the colour of the dark surface at the time of the young moon.

M. de Birto. L'ILE DE PINHEIROS
M. d'Aranjo. 7th Sept., 1858.

"Astr. Nachr.," Vol. xlix., p. 280.

Moonaltern brighter an darker than surrounding (Query.)

MM. de Birto et d'Aranjo ont faite une observation curieuse, et qui indiquerait que la vision de la lune aurait été alternativement positive et négative. A partir du 1er contact, disent-ils, la lune continuant toujours sa marche vers l'orient, se montra parfaitement ronde et obscure jusqu'à 10 h. 5 m. 10 s. instant où elle s'approchait des taches obscures qu'on apercevait dans le soleil. Nous avons remarqué que le limbe inverse était plus clair et qu'après que les taches se furent recouvertes, la couleur obscure du reste de l'astre est revenue.

M. de Mello. PARANAGUA,
M. Liais. 7th Sept., 1858.

"Astr. Nachr.," Vol. xlix., p. 279.

Moon's liml traced outsi the sun's di but later on could not b seen. Imag dark moon projected or ground glas

Avec une lunette de quatre pouces d'ouverture, M. de Mello l'a aperçue [*i.e.* the moon] se prolongeant hors des cornes solaires dans l'espace de 4 à 5 minutes.

M. Liais, qui avait quatre lunettes sur la même monture, n'a pu voir ce prolongement dans une lunette de deux pouces grossissant soixante fois, ni dans sa lunette divisée, mais dans la plus petite de ces lunettes qui grossissait trente fois, il a pu suivre la contour de la lune hors des cornes du soleil jusqu'à une distance de 7″ à 8″, surtout près de la corne inférieure en apparence. Avec sa lunette de trois pouces et le grossissement de 179 fois, il a vu le prolongement de la lune pendant une espace de 2′ l'environ du coté de la corne inférieure en apparence. Ces observations ont eu lieu entre 10 h. 7 m. et 10 h. 12 m. Plus tard le même observateur a cherché de nouveau, mais sans succès, à revoir le limbe de la lune hors du contour du soleil.

A peu près vers l'instant ou avaient lieu ces observations, l'image de la lune projetée sur une glace dépolie avec un objectif de trois pouces et de 2·184 m. de longeur focale, était vue en entier et très distinctement. Cette image projetée de la lune en dehors du contour solaire paraissait sur la glace dépolie plus blanche que la région voisine du ciel. Cette apparence a été vue encore à 10 h. 40 m., mais plus faible. Plus tard il n'a pas été possible de la revoir.

Un phénomène très singulier et tout à fait nouveau qui s'est produit est l'apparition de cette image sur les photographies* du soleil tirées à 10 h. 6 m. 56·4 s.; 10 h. 8 m. 17·9 s.; 10 h. 10 m. 59·6 s.; et 10 h. 11 m. 36·6 s.; surtout sur les deux premières.

Rev. W. R. Dawes. HADDENHAM, BUCKS,

18th July, 1860.

"Monthly Notices," Vol. xxi., p. 26.

The moon's limb, just off the disc of the sun and close to it, was repeatedly examined by placing portions of it in a small field of my solar eyepiece, from which the sun was excluded, and using as light a shade as my eye could comfortably bear. No light on any part of the moon's edge could be even suspected.

* For further particulars as to the visibility of the lunar limb in the photographs, see the memoir of Dr. Liais.

Prof. C. Bruhus. Taragona,
18th July, 1860.

"Berichte der Kön. Sächs. Gesellschaft der Wissenschaften Mathematisch—Physikalische Classe," Sitzung am 12ten Dec., 1860, p. 221.

Part of moon outside sun o seen 20 sec. fore totality. Moon always black.

Man hat behauptet, dass bei totalen Finsternissen der ganze Mond bereits geraume Zeit vor Anfang der Totalität sichtbar werde, und dass er nicht immer ganz schwarz, sondern hin und wieder gefärbt erscheine. Um zu untersuchen, ob diese Wahrnehmungen sich bei der gegenwärtigen Finsterniss zeigen würden, sah ich oft in das Dollond'sche Fernrohr und auch in den Cometensucher, habe aber bis kurz vor Anfang der Totalität (20 Secunden vorher) nur immer vom Monde soviel gesehen als sich vor der Sonnenscheibe befand und dieser Theil war stets kohlschwarz.

Herr C. Haase. Valencia,
18th July, 1860.

"Astr. Nachr.," Vol. liv., p. 339.

Moon's limb could not be outside sun an hour befo totality. 10 before totali and 10 min. totality it co be traced fo short dista

Um 2 h. 30 m. [37 minutes before totality] nahm ich das Blendglas eine Zeitlang weg und entfernte den hellen Theil der Sonne aus dem Gesichtsfelde, um zu sehen, ob man etwas von dem Umriss des dunkeln Mondrandes ausserhalb des Sonnendiscus erblicken konnte; jedoch zeigte sich noch nichts dergleichen.

Um 2 h. 59 m. sah ich (bei wieder vorgenommenem Blendglase) dass man am südlichen Rande des Mondes allerdings dessen Contour auf eine Distanz von etwas mehr als eine Quadratseite des Micrometers ausserhalb der Sonnenscheibe erkennen konnte. Der Mondrand war hier durch einen schmalen weissen Lichtsaum begreuzt, der in der Nähe des Sonnenrandes am intensivsten war, dessen Breite ich dort zu 30″ schätzte, und der dann spitzig am Mondrande sich verlief. So viel Mühe ich mir auch gab, so konnte ich doch von der weiteren aüsseren westlichen Peripherie des Mondes nichts sehen,

(p. 341.) Sehr interessant war es mir, zu bemerken, dass um 3 h. 20 m. der untere (also nördliche) schwarze Mondrand ausserhalb des Sonnendiscus sichtbar wurde, und zwar nur in derselben Ausdehnung, wie es vorhin der entgegengesetzte Rand gewesen war. Dasselbe schmale weisse Licht

begreuzte ihn. Jetzt bei der Rückbildung der Sonnenfinsterniss war am oberen (also südlichen) Theile dagegen nichts von dieser Erscheinung zu bemerken. Um 3 h. 35 m. war jedoch jede Spur dieses Lichtes verschwunden.

Padre A. Secchi. DESIERTO DE LAS PALMAS, 18th July, 1860.

"Comptes Rendus," Vol. li., p. 157.

Could not be seen at first. At 2 h. 19 m. visible—later on lost.

Quelques minutes après le commencement, je cherchai à voir le disque de la lune à l'extérieur du soleil, mais je ne pus y parvenir. A 2 h. 19 m. je réussis à le voir très-nettement dans une étendue d'environ 10° au plus; mais quelque temps après la lune disparut, et depuis lors elle ne put être observée que par instants. Cela serait-il dû à la diversité des parties de la couronne solaire sur laquelle le disque de la lune se projetait?

Don Antonio Aguilar. DESIERTO DE LAS PALMAS, 18th July, 1860.

"Über Totale Sonnenfinsternisse," Dr. von Mädler, p. 26.

13 m. after the beginning, moon's limb seen for 20° outside above, below only half as far.

Dreizehn Minuten nach dem Anfange sah ich schon den Mondrand ausserhalb der Sonnenscheibe, oben bis zu 20°, unten nur etwa halb so weit.

Mr. R. W. H. Hardy. SION HILL, BATH, 31st Dec., 1861.

"Monthly Notices," Vol. xxii., p. 91.

When the moon reached the middle of the eclipse, ... by carefully excluding every ray of direct solar light, the moon's edge was traceable upwards to a considerable distance from both cusps, as if illuminated by a faint twilight.

Capt. W. Noble. MARESFIELD, 6th March, 1867.

"Monthly Notices," Vol. xxvii., p. 185.

About 22 h. 15 m. 15 s., L. M. T., I could trace the moon's limb for one or two minutes of arc beyond the cusps of the sun; the contrast between its jet blackness and the blue of the sky being very apparent.

Dr. Ed. Weiss. RAGUSA,
6th March, 1867.

Vol. lv. of the "Sitzb. d. k. Akad. d. Wissensch.," ii. Abth., May 1867.

(p. 17.) Der Mondrand war weit über die Sonnenscheibe hinaus zu bemerken und von einem schwachen gelben Lichtschein umsäumt, der unmittelbar am Sonnenhorne am breitesten und unmittelbar längs des Mondesrandes am hellsten war, und sich von da weg allmälig im hellen Hintergrunde verlor.

The moon's l was to be tra far outside th sun's disc, su rounded by a yellow light.

Mr. R. F. Chisholm. MADRAS,
18th Aug., 1868.

"Report of the Government Astronomer upon the Observations of the 1868 Eclipse."

(p. 28.) I turned the crescent out of the field of view, and removed the dark glass, but could not get the faintest indication of the dark limb of the moon upon the sky.

Mr. J. Tebbutt. WINDSOR, NEW SOUTH WALES,
18th Aug., 1868.

"Monthly Notices," Vol. xxix., p. 2.

A careful scrutiny satisfied me that not the slightest portion of the moon's limb could be even faintly distinguished beyond the cusps.

Prof. G. W. Hough. MATTOON, ILLINOIS,
7th Aug., 1869.

"Journal of the Franklin Institute," Jan. 1870, p. 61.

As the time drew near for the first contact of the moon's limb, each observer examined carefully the region where the moon was expected, to see whether it would be visible before contact with the solar disc. The closest scrutiny of five observers failed to discover it.

Mr. W. S. Gilman, Jun. ST. PAUL JUNCTION, PLYMOUTH COUNTY, IOWA, 7th Aug., 1869.

"Washington Observations," 1870, Appendix ii., p. 174.

[Immediately after first contact] the moon's limb [was] visible away from the sun's disc a few minutes from the point of contact on either side. Though I had looked with great care for the approaching moon some minutes previous to contact, I saw nothing of it until *after* I had seized the black excrescence.

Prof. J. C. Watson. CARLENTINI, SICILY, 22nd Dec., 1870.

"United States Coast Survey Report for 1870," Appendix xvi., p. 20.

Being fully convinced that the bright corona, whose limit is well defined, is really an appendage of the sun, composed of glowing gas, I concluded to observe carefully whether it might not be visible during the partial eclipse; and I was able to see it distinctly, by the visibility of the limb of the moon beyond the limb of the sun. At 20 h. 38 m. chronometer time, or only ten minutes before the last contact, I could distinctly trace the limb of the moon to a distance of two minutes of arc from the sun's limb.

CHAPTER VI.

THE WHOLE CONTOUR OF THE MOON SEEN BEFORE OR AFTER TOTALITY.

OBSERVERS differ greatly as to the length of time during which the whole disc of the moon can be traced—before or after the total phase.

1842.	**Arago.**	About 20 m. before totality.
	Bouvard.	38 m. after totality, almost the whole of the outer limb seen.
1851.	**Pettersson.**	15 s. after totality.
	Hind.	About 25 m. before totality (see extract on p. 39).
1860.	**De la Rue.**	Several minutes before totality.
	Oom.	4 m. after the corona had disappeared.
	Goldschmidt.	11 m. after totality.
	Winter.	When five-sixths of the sun's disc were covered.
	Bruhns.	2 m. after totality.
	G. Rumker.	$1\frac{1}{2}$ m. before totality.
1869.	**Lane.**	2 m. 5 s. after totality.

At the eclipse of 1842, ARAGO and BOUVARD remarked that the portion of the lunar limb nearest to the sun was more easily traceable than the rest.

M. Arago. PERPIGNAN, 8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 372.

Quarante minutes environ après le commencement de l'éclipse* du 8 juillet, je vis le contour de la Lune *se dessinant sur le ciel.* Il formait le prolongemente exact de l'arc circulaire obscur qu'une autre portion du même limbe traçait sur la surface du soleil, et se réunissait à lui dans deux points du limbe radieux de ce dernier astre. Cet arc *extérieur* paraissait mieux terminé à gauche (dans ma lunette) qu'à droite. Il était *plus visible près* de la périphérie du soleil qu'ailleurs.

* About twenty minutes before totality.

M. Eugène Bouvard. DIGNE, 8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 373.

Whole limb seen 38 m. after totality.

A 6 h. 40 m. (38 m. *après* le moment de l'obscurité totale, et 23 m. avant la fin de l'éclipse), j'ai vu presque entièrement le disque de la lune, comme lorsqu'on aperçoit la lumière cendrée; mais le bord qui se détachait du soleil était toujours plus lumineux.

Lieut. C. A. Pettersson. GÖTTENBURG, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., pt. i., p. 69.

About 15 s. before the totality I saw, through my red glass shade, the continuation of the limb of the moon beyond the limb of the sun, both above and below the luminous segment which still remained.

Mr. De la Rue. RIVABELLOSA, SPAIN, 18th July, 1860.

"Bakerian Lecture on the Eclipse of 1860,"* Phil. Trans., pt. i., 1862, p. 23.

Several minutes before the totality the whole contour of the brown-looking lunar disc could be distinctly seen in the heavens.

Lieut. F. A. Oom. ALTO D'URBANEJA, NEAR POBES, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

I was able to trace the whole circumference of the moon until four minutes after the corona had entirely disappeared.

Herr Hermann Goldschmidt. VICTORIA, 18th July, 1860.

"Astr. Nachr.," Vol. lvi., p. 308.

Contour of moon seen for 11 m. after totality.

Ich konnte die Umrisse des Mondes noch 11 Minuten nach der Totalität sehen, sich grau vom etwas hellerem Himmelsgrunde ablösend.

* See also letter to the *Times*, for August 9, 1860, from Mr. De la Rue.

Mr. R. Winter. MOUNTAIN OF SAN LORENZO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

We were stationed about 6150 feet above the level of the sea. When five-sixths of the sun's disc were covered, the whole circle of the moon became visible—the edge of that portion which as yet had not passed over the sun appearing like a thin film of bright light.

Prof. C. Bruhns. TARAGONA,
18th July, 1860.

"Berichte der Kön. Sachs. Gesellschaft der Wissenschaften—Math. Phys. Classe," Sitzung am 12ten Dec., 1860, p. 227.

Als ich 2 Minuten nach dem Ende der Totalität den Mondrand verfolgte, konnte ich noch den ganzen Umfang der Mondscheibe erkennen; 5 * Minuten später war es nicht mehr möglich; ausser dem Theile, welcher vor der Sonnenscheibe sich befand, war nichts zu erkennen. Two min after tot whole of disc seen later no limb out visible.

Herr Geo. Rumker. CASTELLON DE LA PLANA,
18th July, 1860.

"Die Totale Sonnenfinsterniss am 19ten Juli, 1860," 4to, Hamburg, 1861.

(p. 6.) Die Corona hatte sich wohl schon 1½ Minuten vor dem Verschwinden der Sonne gebildet, und die ganze Mondscheibe war jetzt sichtbar. Whole ble 1½ m totality;

Mr. J. Homer Lane. DES MOINES, IOWA,
7th Aug., 1869.

"Washington Observations," 1870, Appendix II., p. 170.

The end of totality having arrived, I thought it well to ascertain how long the eastern, or far limb, of the moon could be seen. With this view I continued to watch that part of the limb comprising most of the lower right-hand quadrant, and some adjoining part, perhaps, of the upper right-hand quadrant, as seen inverted in the telescope. For some little time it continued to be strongly marked; for a considerable length of time it was easily seen; and for a still longer time it could be unmistakably followed by the aid of a little motion given to the telescope. As the last faint traces were being obliterated I noted the time by the chronometer, 11 h. 3 m. 30 s. Comparing this with the time of third contact as noted by Prof. Hilgard, I find it to have been 2 m. 5 s. after the end of totality.

* See also "Astr. Nachr.," vol. liv., p. 314.

CHAPTER VII.

THE CUSPS OF THE SOLAR CRESCENT SEEN AS COLOURED.

Weiss, in the *Sitzungsbericht* of the Vienna Academy, gives a coloured diagram of the solar crescent as it appeared to him during the eclipse of 1867, when the sun was about seven-eighths covered. Both cusps are represented as of a brick-red colour, fading into orange at a distance of 8′ or 10′ from their points. Weiss, Chisholm, and Cacciatore, agree in describing the reddish colour as being at the cusps only, though Lespiault and Burat speak of the whole exterior limb of the crescent as being of a tender rose colour, and Cacciatore appears to have seen a violet tint extending over the whole crescent, as well as the red cusps and a red fringe adjacent to the moon's limb. The colour of the cusps is described by

Weiss	as	röthlichgelb, intensiver an der Spitze.
Chisholm	as	a sickly yellowish orange, as seen through a neutral-tint dark glass.
Cacciatore	as	violacea tendente al rosso verso le cuspidi.

M. Lespiault. Briviesca,
M. Burat. 18th July, 1860.

"Observations sur l'Eclipse Totale du 18 Juillet, 1860," par MM. Lespiault et Burat, p. 3.

Dans les premières secondes qui ont précédé l'obscurité . . . . . le contour extérieur [du petit croissant solaire] n'était pas aussi net que d'habitude, et se colorait d'un rose tendre.

Dr. Ed. Weiss.

RAGUSA,
6th March, 1867.

Vol. lv. of the "Sitzb. d. k. Akad. d. Wissensch.," ii. Abth., May 1867, p. 17.

Das obere Horn der Sonne war röthlichgelb, intensiver an der Spitze, und allmälig schwächer werdend gegen den breiteren Theil der Sonnensichel zu.

The upper ho reddish-yello most intense : the point.

Mr. R. F. Chisholm.

MADRAS,
18th August, 1868.

Report of the Government Astronomer upon the observations of the 1868 Eclipse, p. 28.

I looked carefully for any change of colour on the sun, but could not distinguish any. At about 9 h. 38 m., the time of the greatest obscuration, I fancied the sun's cusps turned a sickly yellowish orange; but as I was observing with a warm neutral dark glass at the time, I cannot be certain of the effect, and think it probably due to the fatigued retina.

Prof. G. Cacciatore.

AUGUSTA,
22nd Dec., 1870.

"Rapporti della Commissione Italiana," p. 44.

La falce solare quanto più attenuavasi prendea una tinta violacea tendente al rosso verso le cuspidi, e questa tinta mostravasi più intensa dalla parte della luna.

Solar crescent violet, tending red towards t cusps.

CHAPTER VIII.

MOON SEEN AS RED BEFORE TOTALITY.

MURRAY, HIND, ROTTENBERG, and RUMKER all agree in describing the colour seen by them upon the moon's disc as being red. MURRAY says that a crimson glow seemed to pass over the moon, and then disappeared; the others describe the colour as appearing at various periods of the partial phase, and from their language it would seem that it continued visible till the end of the eclipse. ROTTENBERG describes the colour as being unequally distributed, and MURRAY says that it extended to the upper cusp. HIND and RUMKER seem to speak of the disc as of one uniform tint.

Time at which the colour appeared :—

1851.	**Murray.**	When the moon had passed over about a third of the sun.
	Hind.	30 m. after beginning of eclipse.
1860.	**Rottenberg.**	About 25 m. before totality.
	Rumker.	Just before totality.

Colour observed :—

1851.	**Murray.**	A deep crimson glow.
	Hind.	A dull coppery red.
1860.	**Rottenberg.**	A reddish brownish light.
	Rumker.	Röthlich wie eine erlöschende Kohle.

Mr. Murray.

YARROWLUMLA,
31st January, 1851.

"Monthly Notices," Vol. xii., p. 31.

When the moon had passed over about a third of the sun, a deep crimson glow seemed to pass over his face, extended to the upper cusp, and then disappeared.

Mr. Hind. RŒVELSBERG, NEAR ENGELHOLM,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., pt. i., p. 82.

During the progress of the eclipse I looked repeatedly for any appearance of light or colour upon the moon's surface. For thirty minutes nothing of the kind was perceptible; but at 3 h. 40 m. her surface appeared of a dull coppery red, and the outline of her disc could be traced by the contrast of this ruddy tinge with the neutral tint of the field of the telescope.

Baron de Rottenberg. VALENCIA,
18th July, 1860.

MS. Observations of the Himalaya Expedition.

At 2 h. 32 m. 30 s.* I saw a *reddish brownish* light over the upper part of the moon, extending nearly to the limb on the right hand, and much broader towards the left hand. The light was seen throughout the greater part of the remainder of the eclipse.

Herr G. Rumker. CASTELLON DE LA PLANA,
18th July, 1860.

"Die Totale Sonnenfinsterniss am 18ten Juli, 1860," 4to, Hamburg, 1861, p. 16.

[Just before the totality] Der dunkle Mond leuchtete meinem Auge röthlich wie eine erlöschende Kohle. Dark moon red like a dull glowing coal.

* About twenty-five minutes before totality.

CHAPTER IX.

SHADOW BANDS.

THE evidence as to the time at which the shadow bands have made their appearance is somewhat conflicting. FAUVELLE, THIEL, four persons near Rastenburg, JACOB, RICKARD, and BERGSMA, describe them as being visible for a short time both before and after totality, while two persons in Ortelsburg, HAASE, IBACH, and MULLER, speak of them as visible during totality. SERGIANT, RICKARD, and LANG, on the other hand, particularly noticed that they were not visible during the total phase. The shadows have been observed during an annular eclipse, see GOLDSCHMIDT's account of his observations in 1820 (under GOLDSCHMIDT, 1860), and they have been seen outside the path of totality, see SAYA-MOLETI, 1870.

The time at which they have been perceived before totality, and during which they have remained visible after totality, varies with the different observers from a few seconds to as much as five minutes, thus :—

1842.	Fauvelle.	At the instant at which the eclipse was about to become total . . . . and for 5 or 6 seconds after totality.
	Savourin.	Some instants before the complete disappearance of the sun.
1851.	Sergiant.	Some instants before totality ; they ceased at the moment the eclipse became total.
	Thiel.	A few seconds before totality . . . . and after totality.
	Four persons near Rastenburg.	As the last ray of sunlight disappeared, and at the end of totality.
	Two persons in Ortelsburg.	During totality.
1860.	Jacob.	About 3 minutes before totality they were seen for 30 seconds, and similarly after totality.

	Goldschmidt.	(About 3 to 4 minutes before the formation of the ring in the annular eclipse of 1820.)
	Thompson.	Before totality.
	Haase.	During totality.
	Ibach.	Quite shortly before the beginning of totality and during totality.
1861.	Poulain.	About a minute before totality.
	Dutaillis.	
1868.	Beale.	About a minute before totality; they continued for about 30 seconds.
	Fauro.	No time mentioned.
1870.	Legnazzi.	Just after giving the signal for third contact (beginning of totality).
	Muller.	Just after the beginning of totality.
	Omodei.	At the commencement of totality.
	Costa.	No time given.
	Seguenza.	
	Saya-Moleti.	
	Maucini.	A few minutes before totality.
	Frisiani.	No time mentioned.
1871.	Rickard.	5 seconds before totality and for four seconds after totality.
	Bergsma.	3 minutes before totality and for five minutes after totality.
	Lang.	Not visible during totality, though they appear to have been seen both before and after totality.
	Scheffer.	No time mentioned.

The shadow bands are frequently described as being similar in appearance to the moving lines of light and shade which may be seen when sunlight is reflected from the surface of rippling water on to some adjacent wall. Beale and Muller * describe the shadows as similar to those seen upon the ground when the sun shines through heated air or smoke.

Thiel, and four persons near Rastenburg in 1851, speak of the bands as appearing to move round a centre like the spokes of a wheel, but they are usually described as wavy lines of light and shadow moving rapidly forward over the surface of the ground. Savourin in 1842, and the peasants in the neighbourhood of Vitoria in 1860, described the phe-

* Query also the people near Rastenburg in 1851.

nomenon as consisting of patches of light; and RICKARD describes the shadows as having the appearance of a loose fleece or scales.

SAVOURIN, a person mentioned by SCHMIDT in 1851, and the peasants in the neighbourhood of Vitoria, agree in describing the patches or bands as coloured; all the other observers speak of them as shadows separated by brighter interspaces, thus :—

<table>
<tr><td>1842.</td><td>Savourin.</td><td>Ombres et taches lumineuses, rouges, jaunes, bleues, et blanches.</td></tr>
<tr><td>1851.</td><td>Sergiant.</td><td>Ombres flottantes.</td></tr>
<tr><td></td><td>Thiel.</td><td>Helle und dunkle Streifen, farblos.</td></tr>
<tr><td></td><td>Four persons near Rastenburg.</td><td>Lange, gerade, helle und dunkle Streifen . . . . farblos.</td></tr>
<tr><td></td><td>Two persons near Ortelsburg.</td><td>Einer von ihnen sah an dem Schatten prismatische Farben.</td></tr>
<tr><td>1860.</td><td>Jacob.</td><td>Thin parallel lines of shadowy waves.</td></tr>
<tr><td></td><td>Peasants in the neighbourhood of Vitoria.</td><td>Gelbe Flecken.</td></tr>
<tr><td></td><td>Weyer.</td><td>Undulating shades or images.</td></tr>
<tr><td></td><td>Thompson.</td><td>Bright waving lines of light.</td></tr>
<tr><td></td><td>Haase.</td><td>Tanzende Lichter.</td></tr>
<tr><td></td><td>Ibach.</td><td>Schillernde Lichtstreifen.</td></tr>
<tr><td>1861.</td><td>Poulain.</td><td rowspan="2">La nuance était une ombre claire qui a paru dégradée sur les bords.</td></tr>
<tr><td></td><td>Dutaillis.</td></tr>
<tr><td>1868.</td><td>Beale.</td><td>Shadows in straight lines, the shades and lights running imperceptibly into each other.</td></tr>
<tr><td></td><td>Fauro.</td><td>Wellenförmige Linien.</td></tr>
<tr><td>1870.</td><td>Legnazzi.</td><td>Righe volanti, nere e fuligginose.</td></tr>
<tr><td></td><td>Muller.</td><td>Ombre vacillante . . . . come spinte da forte vento, parallele fra loro.</td></tr>
<tr><td></td><td>Omodei.</td><td rowspan="4">Ombre volanti.</td></tr>
<tr><td></td><td>Costa.</td></tr>
<tr><td></td><td>Seguenza.</td></tr>
<tr><td></td><td>Saya-Moleti.</td></tr>
<tr><td></td><td>Maucini.</td><td>Zone bianco e chiare.</td></tr>
<tr><td></td><td>Frisiani.</td><td>Striscie dell' ombra.</td></tr>
<tr><td>1871.</td><td>Rickard.</td><td>Shadows.</td></tr>
<tr><td></td><td>Bergsma.</td><td rowspan="3">Flying shadows.</td></tr>
<tr><td></td><td>Lang.</td></tr>
<tr><td></td><td>Scheffer.</td></tr>
</table>

The estimates which have been made of the breadth of the bands differ from 5 or 6 centimetres to half a metre, thus:—

1861.	**Poulain.** **Dutaillis.**	Leur largeur et leur espacement étaient à-peu-près égaux, et mesuraient environ 10 centimètres.
1870.	**Legnazzi.**	Di differente altezza, la media me parve di 25 in 30 centimetri.
	Muller.	Della larghezza apparente di circa mezzo metro.
	Costa. **Seguenza.**	La larghezza era stimata da essi di 7 in 8 centimetri.
	Maucini.	Della larghezza di circa 30 centimetri.
1871.	**Bergsma.**	5 to 6 centimetres.
	Scheffer.	1½ decimetres.
	Lang.	About 3 decimetres.

The rate at which the shadows move over the ground has been variously estimated. It appears certain, however, that the rate of their motion is not to be compared with the velocity with which the moon's shadow travels over the earth. IBACH and BEALE speak of the motion as if it was too rapid to be easily followed, while SAVOURIN, BERGSMA, LANG, and SCHEFFER assign a much more moderate pace to the shadows, thus:—

1842.	**Savourin.**	Les enfants les poursuivaient et essayaient de mettre la main dessus.
1851.	**Sergiant.**	Qui traversaient la plaine en se suivant avec rapidité.
	Thiel.	Eine rollende schnelle Bewegung.
	Four persons near Rastenburg.	Sich schnell über die Ebene hinbewegten.
1860.	**Jacob.**	Moving rapidly over the rocks.
	Ibach.	Rasch hin und her . . . . als wenn die Sonne eine entfernte Fensterscheibe bescheine, das Fenster dann rasch geöffnet oder geschlossen werde.
1868.	**Beale.**	The motion was too rapid to allow of the breadth of the shadows being estimated.
1870.	**Maucini.**	Correre rapidamente.
	Frisiani.	Si succedono sinuose e rapide.
1871.	**Rickard.**	Immediately after totality the shadows began to *creep* over the screen . . . . The shadows travelled quicker after totality.

Bergsma. **Lang.** **Scheffer.**	They moved parallel to themselves slowly; their velocity over the wall was about that of a horse in a moderate trotting pace.

The direction of the motion of the shadow bands does not appear to coincide with the direction of the motion of the moon's shadow over the earth, nor does it appear to bear any constant relation to this direction, as will be evident from the following table:—

		Direction of Motion of Shadow Bands.	Approximate Direction of Motion of the Moon's Shadow
1851.	**Thiel.**	N. to S. on a N. and S. wall.	N.W. to S.E.
	Four persons near Rastenburg.	N.W. to S.E. over the fields.	N.W. to S.E.
1860.	**Peasants in the neighbourhood of Vitoria.**	W. to E.	N.W. to S.E.
	Thompson.	Flickered one after another over the ground parallel to my line of sight with the sun (*i.e.* N.E. to S.W. or from S.W. to N.E.)	N.W. to S.E.
1861.	**Poulain.** **Dutaillis.**	On an E. and W. wall the direction of the bands is described as 45° beneath the left shoulder (observer's back evidently turned to the sun).	W. to E. nearly.
1868.	**Beale.**	Wall facing sunrise, from left shoulder to right foot (observer's back evidently turned to the sun).	W. by S. to E. by N.
	Fauro.	From E. to W. on a horizontal surface.	N.W. by W. to S.E. by E.
1870.	**Maucini.**	From W. to E. over the ground.	W.S.W. to E.N.E.
1871.	**Bergsma.** **Lang.** **Scheffer.**	On a wall directed E. 13° 30′ N. to W. 13° 30′ S. The shadows made an angle of 45° from the vertical towards the W., and moved from E. to W. On a horizontal table they made an angle of 45° with the wall, and moved from S.E. to N.W.	N.W. by W. to S.E. by E.

We are unfortunately unable to supply information as to the direction of the wind at the stations where the shadow bands have been observed.*

Mr. LANG describes the shadows as alternately increasing and diminishing in strength; and JACOB and BEALE describe them as disappearing after being visible for 30 seconds, JACOB at 2½ minutes before totality, and BEALE at half a minute before totality.

LIAIS and D'ABBADIE state definitely that they looked for flying shadows but failed to see any traces of them. The observations made at Tjilentaf and Lawoengen (see BERGSMA 1871) must also be ranked under the head of negative evidence.

M. Fauvelle. PERPIGNAN,
8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 392.

Au moment où l'éclipse allait devenir totale, je vis les derniers rayons du Soleil onduler fortement et avec vitesse sur la *muraille blanche* d'un des établissements militaires du rempart Saint-Dominique. L'effet peut être comparé à ce qu'on observe lorsque la lumière solaire tombe sur un mur ou sur un plafond, après avoir été réfléchie à la surface d'une nappe d'eau agitée.

Just befo[re] for 5 s. or after, tot[ality,] dulations seen upo[n] as if refle[cted] from trou[bled] water.

Le même phénomène se reproduisit au moment de l'émersion du Soleil. Les ondulations, fortes d'abord, s'affaiblirent graduellement et disparurent tout à fait au bout de 5 à 6 secondes.

* The following information may, however, be of interest. The wind is recorded as blowing from the N.W. at Frauenburg and Christianstadt during the eclipse of 1851, and as being nearly calm (or a slight breeze from the W.) at Rœvelsberg. During the eclipse of 1860 at Bezana it was feeble and northerly; at Fuente del Mar, N.W.; at Orduna, N., with an upper current of S. wind; at La Guardia, N.W.; at Tarazona, at the beginning of the eclipse, S.W., then it shifted to W. and N.W., and during totality it was N.; at Valencia, S.E. before totality, during totality E.N.E., and after totality S.E. Towards the commencement of the eclipse of 1868 Ross at Mantawalu Kiki (the same station as that of Padre Fauro) registered the wind as N.N.W., and he makes no note of its having changed during the eclipse. See also the observations of M. Altenoux given in the next chapter. He describes 'un mouvement ondulatoire' seen in the air, going in the same direction, and apparently at the same rate, as the wind, which was blowing.

L'observation a été faite en trois points différents par plus de vingt personnes qui le certifieraient au besoin.

M. Savourin. SEYNE, 8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 393.

Some instants before the sun disappeared, shadows and red, yellow, blue, and white patches of light seen running one after the other.

On a vu ici des ombres et des taches lumineuses courir les unes après les autres, comme paraissent le faire les ombres produites par de petits nuages qui passent successivement sur le Soleil. Ces taches n'étaient pas de la même couleur: il y en avait de rouges, de jaunes, de bleues, de blanches. Les enfants les poursuivaient et essayaient de mettre la main dessus.

Ce phénomène extraordinaire fut remarqué quelques instants seulement avant la disparition complète du Soleil.

M. Sergiant. DANZIG, 28th July, 1851.

"Comptes Rendus," Tome xxxiii., p. 176.

Some instants before totality floating shadows seen moving from N.W. to S.E.

Quelques instants seulement avant l'éclipse totale, je remarquai des ombres flottantes qui traversaient successivement la plaine en se suivant avec rapidité comme des ondes, dans la direction du nord-ouest au sud-est. Elles cessèrent au moment même de l'éclipse totale.

A Workman. DANZIG, 28th July, 1851.

"Astr. Nachr.," Vol. liv., p. 341.

Moving bands of light seen.

Der eine der beiden Arbeiten des Herrn Ibach bestätigte dies [*i.e.*, the observation of Herr Ibach made in 1860], mit dem Bemerken, dass er während der Sonnenfinsterniss im Jahre 1851, wo er sich in Danzig befunden, etwas ganz ähnliches gesehen habe.

* For accounts of observations by M. d'Hombres-Firmas at Alais, M. J. Guerin at Avignon, M. Lentheric, at Montpellier, MM. Pinaud and Boisgiraud, at Toulouse, see "Annuaire pour 1846 du Bureau des Longitudes," pp. 395-9.

Dr. Julius Schmidt. RASTENBURG,
Herr Thiel. 28th July, 1851.
Four persons near Rastenburg.
Herr Billerbeck.

"Beobachtung der Totalen Sonnenfinsterniss," Schmidt, Bonn, 1852.

(p. 20.) Die sicherste Beobachtung dieses Phänomens verdanke ich dem Herrn THIEL, Besitzer des Gutes Neumühl bei Rastenburg, den ich ersucht hatte, die eine der Sonne zugewendeten Seite eines ziemlich grossen Hauses auf seinem Gute, mit weisser Farbe überziehen zu lassen. Dies wurde ausgeführt und zwar an einer Wand, die vom Giebel bis zum Boden kaum ein Fenster hatte. Herr THIEL stand während der Finsterniss mit seiner Umgebung über 30 Schritte westlich von der Wand entfernt. Wenige Secunden von dem Verschwinden des letzten Sonnenstrahls bemerkte er eine rollende schnelle Bewegung von hellen und dunklen Streifen auf jener Wand, farblos, die hellen Zwischenräume breiter als die dunkleren Streifen, und zwar in der Art vorüberziehend, dass, wenn sie auch im Allgemeinen senkrecht standen sie doch offenbar während ihres von Norden nach Süden gerichteten Laufes ein etwa auf dem Boden befindliches Centrum der Bewegung hatten, so dass sich also jene Linien wie die Speichen eines Rades um eine Axe zu drehen schienen. Diese Beobachtung ist völlig sicher. Sie wurde ebenso gemacht, als das Sonnenlicht wieder erschien und findet ihre Bestätigung in der Aussage von vier andern Personen, welche mir am Abende nach der Finsterniss über diesen Punkt ihre Bemerkungen mittheilten. Sie befanden sich kurz vor der Totalität westlich von Rastenburg auf der Königsberger Chaussee, und hatten nahezu in der Verlängerung dieser Strasse, etwas links die Sonne vor sich. Als der letzte Strahl verschwinden wollte, bemerkten sie sämmtlich gleichzeitig eine grosse Anzahl von langen, geraden, hellen und dunklen Streifen, welche sich schnell über die Ebene, über die Kornfelder und die Strasse hinbewegten, ungefähr in der Richtung von Nord-west nach Süd-ost, und zwar so, dass sie links auf dem Felde in der Richtung nach der Sonne hin ein Centrum zu haben schienen, um welches sie (ganz wie in Neumühl) sich wie die Speichen eines Rades um eine und dieselbe Axe drehten. Am Ende der Totalität wiederholte sich das Phänomen in derselben Weise. Alle hellen und dunkeln Streifen waren farblos.

An andern Orten in der Umgegend von Rastenburg, hat man die Erscheinung ebenfalls und vielfach bemerkt, doch sind die Aussagen darüber zu wenig bestimmt, als dass ich sie hier anführen sollte. Mehrfach finde ich sie so beschrieben, als hätte man schnellziehenden Rauch in zitternder Bewegung sich über die Fläche hin bewegen gesehen. Nur eine Beobachtung, wenn sie anders sich wirklich auf die Undulationen bezieht, spricht von Farben. Was BILLERBECK mir darüber schriftlich mittheilt, ist Folgendes: In Ortelsburg nämlich sahen zwei Personen den Schatten einer Zoll dicken Stange während der Totalität auf die Wand eines Hauses fallen. Der Eine von ihnen sah an dem Schatten prismatische Farben in folgender Ordnung: Gelb, Grün, Blau, Indigoblau, Violett, Roth, Orange, und ein wenig Gelb.

Coloured shadows seen near Ortelsburg.

Dr. Em. Liais. L'ILE DE PINHEIROS, 7th Sept., 1858.

"Astr. Nachr.," Vol. xlix., p. 282.

Shadows sharply defined at reappearance of sun—no scintillation, no moving shadows, although a cloth was spread to observe them.

A l'œil nu la réapparition du premier point solaire produisit l'effet d'un éclairage par la lumière électrique. Les ombres présentèrent une grande netteté. . . . Il n'était nullement scintillant, et à la station centrale sur un drap étendu dans ce but on n'a remarqué aucune trace des ombres mouvantes et colorées, dont parle ARAGO à l'occasion de l'éclipse de 1842, tant au commencement qu'à la fin de l'obscurité totale. Au palais de St. Christophe la même observation a été faite avec le même résultat négatif.

M. Antoine d'Abbadie. BRIVIESCA, 18th July, 1860.

"Comptes Rendus," Tom. li., p. 708.

No coloured patches seen.

Le vent de l'éclipse fut nul, et pendant le froid piquant qui en accompagna le millieu, nous cherchâmes en vain sur la terre ces plaques colorées qui en de pareils phénomènes ont tant impressionné les spectateurs d'une éclipse totale.

Capt. W. S. Jacob. PEÑA CERRADA, SIERRA DE TOLOÑO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

At 2 h. 47 m. 30 s. [about three minutes before the sun disappeared]

thin parallel lines of shadowy waves were seen moving rapidly eastward over the rocks, accompanied by a flickering light in the air, which lasted nearly 30 s., and a similar appearance was repeated after the totality at 2 h. 56 m.

Herr Herrmann Goldschmidt. VITORIA,
Peasants in the neighbourhood of Vitoria. 18th July, 1860.

"Astr. Nachr.," Vol. lvi., p. 308.

Ich hatte Vorkehrungen getroffen, die beweglichen Schatten auf der Erdoberfläche zu beobachten, die mich in meinen Jugendjahren während einer ringförmigen Sonnenfinsterniss so sehr überraschten, aber es blieb mir keine Zeit, obgleich ich alle Vorkehrungen hierzu getroffen hatte.

Shadow ban[ds] not looked f[or] but they we[re] seen by the people in th[e] neighbourh[ood] as yellow sp[ots] moving from [W.] to E.

Landleute in der Nähe von Vitoria erzählten mir unaufgefordert, dieses Phänomen beobachtet zu haben; sie hatten gelbe Flecken sich von Westen nach Osten bewegen gesehen, und die besonders auf ihren Hemden sichtbar waren. Bei der angeführten ringförmigen Finsterniss von 1820 gingen die Schatten auch von Westen nach Osten im langsamen Zuge und ungefähr 3 bis 4 Minuten vor Bildung des Ringes.

Prof. G. D. E. Weyer. VITORIA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

Undulatory shades or images just before and after the totality were not remarked, although a white cloth was spread by Mr. GOLDSCHMIDT, who kept the phenomenon in remembrance from his childhood.

The Rev. R. A. Thompson. TUDELA,
18th July, 1860.

"The English Churchman," 26th July, 1860.

At five minutes past 3 bright waving lines of light flickered one after another over the ground parallel to my line of sight with the sun. On looking upward from these I found that the sun had already disappeared.

Herr C. Haase. VALENCIA,
Herr Ibach. 18th July, 1860.

"Astr. Nachr.," Vol. liv., p. 340.

To Herr Haase the corona appeared to undulate violently, and the prominences to move round at the same time. Herr Ibach observed moving bands of light on the roof and tower.

[The following observation was made towards the end of totality.] Als ich nochmals mit freiem Auge die Corona betrachtete, schien sie mir heftig zu wallen, und es hatte den Anschein, als ob auf der schwarzen Mondscheibe dunkelrothe Punkte in rapider wirbelnder Bewegung waren. In diesem Augenblick wurde ich durch einen Ausruf des Herrn IBACH abgezogen, der mich auf plötzlich sichtbar gewordene tanzende Lichter auf der Thurmbrüstung aufmerksam machte. . . . Ein rascher Blick ins Fernrohr überzeugte mich jedoch, dass die Corona ganz ruhig war und auf der Mondscheibe keine rothe Punkte sich zeigten.

(p. 341.) Herr IBACH theilte mir auf mein Befragen wegen der von mir selbst nicht wahrgenommenen "tanzenden Lichter" Folgendes mit. Er habe ganz kurz vor Beginn der Totalität seinen Blick nach der dem Phänomene entgegengesetzten Seite des Himmels und der Erde gewandt und habe dann sowohl auf der innern Seite der steinernen Thurmbrüstung, sowie auf dem sanft ansteigenden Thurmdache mehremal einige schillernde Lichtstreifen sich sehr rasch hin und her bewegen sehen. Es sei ähnlich gewesen, als wenn die Sonne eine entfernte Fensterscheibe bescheine, das Fenster dann rasch geöffnet oder geschlossen werde und dadurch das Reflexbild einem andern oft sehr weit entlegenen Punkte zugeworfen werde.

M. Poulain. GOREE, SENEGAL,
M. Dutaillis. 31st Dec., 1861.

"Monthly Notices," xxii., pp. 167-9.

Black fringes seen a minute before totality on an E. and W. wall, making an angle of 45° beneath the left shoulder.

(p. 167.) Vers 1 h. 25 m. on voit des franges noires se dessiner sur le mur de la terrasse d'observation : à 1 h. 26 m. l'éclipse paraît centrale;

. . . .

(p. 169.) Le phénomène des franges noires a été observé un instant avant l'occultation; elles avaient, sur une surface verticale dirigée sensiblement de l'ouest à l'est, une direction de 45° par-dessus l'épaule gauche; leur largeur et leur espacement étaient à-peu-près égaux et mesuraient environ 10 centimètres. La nuance était une ombre claire qui a paru dégradée sur les bords.

Lieut. B. Beale.

ADEN,
18th Aug., 1868.

Vol. lviii. "Sitzb. d. k. Wissensch.," ii. Abth., Dec., 1868.

(p. 21.) About a minute before the total eclipse I observed shadows passing over the sheets* from the upper left to the lower right hand corner: they continued for about thirty seconds.

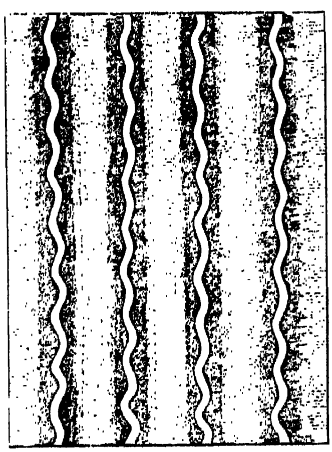
The shadows exactly resemble those that would be caused by smoke passing between the sun and the sheets, except that they were in straight lines and not in patches or curves. They were of uniform darkness, size, and distance; the spaces between each were comparatively light, the shades and lights running imperceptibly into each other.

Padre Fauro.

MANTAWALOC-KAKEE (A CORAL ISLAND IN THE ENTRANCE OF THE GULF OF TOMINI, OR GARONTALO),
18th Aug., 1868.

"Brief des P. F. Fauro an P. A. Secchi über Beobachtungen der totalen Sonnenfinsterniss am 18ten Aug., 1868," p. 12. Halle, 1869.

Ich selbst übernahm den Versuch des Schatten, und hatte die Genugthuung, ihn verwirklicht zu sehen. Auf einem weissen auf möglichst horizontalen Boden gelegten Blatte, sah man eine ungeheure Zahl von Linien verdunkelt und durchbrochen von ebensovielen Linien von einem etwas dunkeln Lichte von Osten nach Westen vorüberziehen. Die Form der Linien war schlangen- oder besser wellenförmig: der Umriss von der Figur kann Ihnen eine, aber nur sehr unvollkommene Idee von der Erscheinung geben; denn es ist schwer, sie zu zeichnen, und die zu grosse Regelmässigkeit die ich in die sich schlängelnden Linien legte, verändert ihren Anblick mehr, als ich wollte.



Wavy lines ing from E. W. seen on horizontal s of paper.

* [Col. Addison says, p. 21,] "Captain Blurton and Lieut. Beale, of the second Queen's regiment, observed the effects on sheets which I had caused to be fastened to the walls of my house facing sun-rise. There was an appearance just before totality as of shadows thrown by

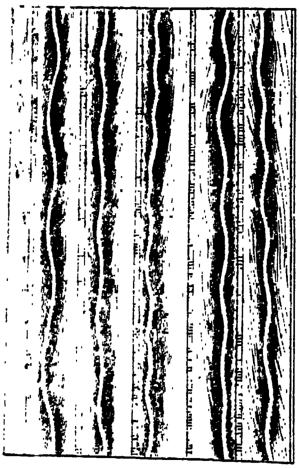
Prof. Legnazzi.

TERRANOVA,
22nd Dec., 1870.

"Rapporti della Commissione Italiana," p. 116.

Just after the beginning of totality flying black lines were seen—the space between them was about 25 or 30 centimeters.

Un fatto per me del tutto nuovo è il seguente: nell' istante che dando a GRIMALDI il segnale del * 3° contatto, distaccai l' occhio dal cannocchiale, e per farmi meglio intendere mi volsi verso di lui, che stava seduto nell' angolo posteriore della baracca, vidi delle righe volanti, nere e fuligginose, o fascie, o bande, striscie, od ombre vacillanti, od ondate oscure, che dire si vogliano, arrampicarsi sulla parete di legno della piramide: partivano del suolo e si elevavano fino alla metà della parete in zone sinuose ondeggianti più o meno oscure di differente altezza; la media me parve di 25 in 30 centimetri. . . . . .



Per formarsi un' idea di queste onde serpentine, basta collocare presso un muro verticale illuminato dal sole una vaschetta d' acqua: se vi si getta per entro un sassolino tosto si vedono arrampicarsi su pel muro delle onde più o meno luminose, che vanno insensibilmente sfumando. . . . . .

Forse tali striscie si saranno presentate anche un momento prima della totalità, ma la mia attenzione era così fissa a cogliere il secondo contatto, che non me ne accorsi menomamente.

Sig. Diamilla Muller.

TERRANOVA,
22nd Dec., 1870.

"Rapporti della Commissione Italiana," p. 176.

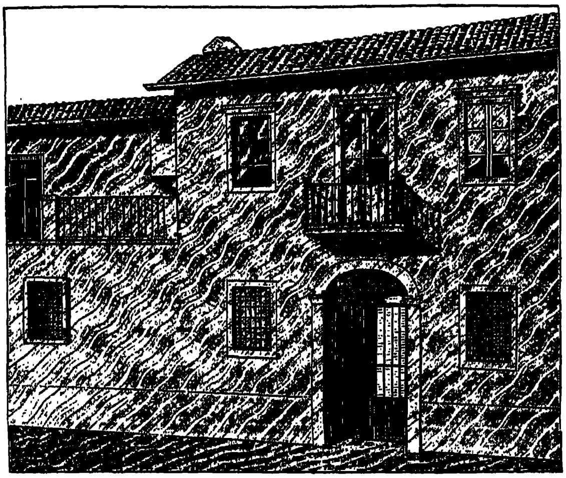
Just after the beginning of totality undulating shadow bands, half a meter broad, seen moving rapidly over the front of a house.

Appena il disco solare fu totalmente oscurato, e scomparso come per incanto l' ultimo raggio di luce, ci fu dato poter osservare il bellissimo fenomeno delle ombre vacillanti e cadenti oblique sulla terra.

smoke—passing from left shoulder to right foot of observers, as their backs were turned to the sun. I had provided my friends with a scale by which if possible to measure the distances between bands of light and shade should they be visible. They noticed that to take any such measure was impossible as the motion was too rapid. The shadows progressed with wave-like motion and with great rapidity, much like the motion of heated air over a furnace."

* The beginning of totality is evidently intended.

Queste ombre avevano la forma di lunghe fascie ondeggianti, mobilissime, come spinte da forte vento, parallele fra loro, della larghezza apparente di circa mezzo metro, separate e distinte le une dalle altre, ma succedentisi con furia, e lunghe quanto era lungo il piano sul quale si proiettavano.*



Per noi queste fascie serpeggianti erano lunghe quanto era alta la casa sulla quale le scorgevamo cadere. Evidentemente la lunghezza apparente di queste ombre è subordinata al piano sul quale si vedono.

Per paragonarle a qualche cosa di noto, erano come l' ombra del fumo a bordo dei piroscafi quando il Sole la proietta sul ponte o sulle acque tranquille del mare.

La loro obliquità era presso a poco l' angolo che formerebbe la verticale del luogo dell' osservazione, col piano tangente il centro del disco del Sole nella sua posizione nel momento del fenomeno.

Sig. Omodei.
Prof. Costa.
Prof. Seguenza.
Sig. Saya-Moleti.

SICILY,
22nd Dec., 1870.

"Rapporti della Commissione Italiana," p. 25.

Il signor OMODEI recatosi ad alcune miglia di distanza entro terra presso al luogo detto *Segnale degl' Inglesi* vide una bella corona, e al sopravvenire della totalità osservò le *ombre volanti*. . . . . . Queste linee furono vedute presso Catania dai signori Professori COSTA e SEGUENZA, i quali le videro scorrere su di un muro bianco vicino, e come arrampicarsi. La larghezza era stimata da essi di 7 in 8 centimetri. La loro direzione

Omodei s ing shad the begin totality: and Segu saw shad 8 centim broad, pa the centr disappea crescent Moleti sa dows, an sun disap though h near Me

* The woodcut is made from a lithographic drawing by Sig. Muller. In a letter accompanying the drawing Sig. Muller says, "Le dessin ci-joint qui représente le bâtiment sur lequel nous voyons ces ombres donne une idée bien pâle du phénomène qu'il est impossible à réproduire dans sa vérité, avec ces oscillations, son tremblement, et son mouvement rapide."

longitudinale era parallela alla falce solare sottilissima. Il signor Sava-Moleti osservò queste frangie e di più un apparente sparire di Sole per una frazione di secondo. Siccome esso era poco fuori di Messina ove l' Ecclisse non potea esser totale, così è a dire che la disparizione istantanea del Sole ivi sia stata cagionata da queste frangie.

Prof. Francesco Maucini. Girgenti, 22nd Dec., 1870.

"Rapporti della Commissione Italiana," p. 210.

A few minutes before totality bright and dark bands, about 30 centimeters broad, moving rapidly from W. to E.

Pochi minuti prima della totalità sul terreno bianco furono osservate delle zone oscure e chiare della larghezza di circa 30 centimetri correre rapidamente le une dietro le altre nella direzione da Ovest verso Est. Esse somigliavano alle onde di un lago mosse dalla brezza, ma con una velocità molto maggiore.

Prof. Frisiani. Avola, 22nd Dec., 1870.

"Rapporti della Commissione Italiana," p. 213.

Moving bands of [illegible] like little waves on the sea.

Furono osservate le striscie dell' ombra nella stazione d' Avola come piccole onde del mare che si succedono sinuose e rapide in un giorno di burrasca su di una spiaggia estesa arenosa, ed erano alternate tra bianco e nero.

Mr. F. M. Rickard. No place given, India, 11th Dec., 1871.

MS. Observations of the 1871 Expedition.

The shadows falling on the two screens were seen only for 5 seconds before totality, and for 4 seconds after totality. No actual bands seen.

Before Totality.—At 5 seconds before totality the shadows commenced. They had the appearance of a loose fleece. Towards the top of the screen the shadow became more dense and took on somewhat the appearance of scales (see figure). At the base of the screen the shadows were lighter and more diffused than at the top. A few shadows came on the N. screen.* During totality no shadows.

* No description of the positions of the screens is given in the MS.

Immediately on the sun's reappearance shadows began to creep over the screen from below upwards. The shadows at the base were denser than at the summit. The appearance was wavy instead of fleecy. The shadows travelled much quicker after than before totality. Shadows crossed the screen up to 4 seconds after totality.

The Comparison of Before and After Totality.

1. The shadows were fleecy before and wavy afterwards.
2. The shadows appeared for five seconds before and four seconds after totality.
3. The shadows travelled quicker after totality.
4. Before totality, the dense part of the shadows was at the summit, after totality they were denser at the base.

Mr. Bergsma.
Mr. Lang.
Dr. Scheffer.

BUITENSORG, JAVA,
12th Dec., 1871.

Letter from Prof. Oudemans on the observations of the eclipse in Java. "Nature," Vol. vi., p. 160.

The flying shadows were very remarkable at Buitensorg. They were observed by persons wholly unacquainted with the phenomenon.

They were seen by Mr. BERGSMA on a white wall directed E. 12° 30′ N. to W. 12° 30′ S., and on a sheet of white paper lying on a table. On the wall the shadows were inclined to the west, making with the horizontal line an angle according to one observer's measurement of 40°, and according to another's of 45°. They moved from E. to W. On the white paper they made an angle of 45° with the edges, which were perpendicular to the wall; they moved on the paper from S.E. to N.W. The phenomenon did not show itself as it is represented in SECCHI's "Le Soleil," p. 158.

The shadows had a breadth of 5 to 6 centimters; they were limited by lines with small irregular undulations; they were separated by regularly illuminated bands; the distance of the shadows was, according to Dr. SCHEFFER (the botanist), $1\frac{1}{2}$ decimeters, and, according to Mr. LANG, about 3 decimeters or a foot. They moved parallel to themselves slowly; their velocity over the wall was about that of a horse in a moderate trotting pace. Mr. BERGSMA saw the shadows from about three minutes before

totality. During totality they were not visible according to Mr. LANG, whom Mr. BERGSMA had requested to pay particular attention to this point, only Mr. LANG saw now and then a slight change in the intensity of the light on the paper.

Immediately after totality the shadows appeared again, increasing and diminishing alternately in strength, but growing gradually less and less distinct, although Mr. BERGSMA continued to see them till about 5 minutes after totality.

Mr. BERGSMA now describes the means proper to obtain more reliable observations on future occasions.

By construction and calculation I have deduced from Mr. BERGSMA's data as to the direction of the shadows on the wall and the paper, the following:

I assumed the inclination of the lines on the wall to be $42\frac{1}{2}^\circ$ with respect to a horizontal line, taking the means between the computations of Messrs. LANG and SCHEFFER. That the shadow lines made an angle of 45° with the edges of the paper, could be understood on two different theories,—viz., that their azimuth was $121\frac{1}{2}^\circ$ and $211\frac{1}{2}^\circ$ (N.E.). Mr. BERGSMA declared that $211\frac{1}{2}^\circ$ was meant.

Now, if we pass a plane through a shadow-line on the wall and its prolongation on the paper, this plane intersects the horizon along a line directed in an azimuth of $31\frac{1}{2}^\circ$ (N.E.), whereas the same plane has an inclination of $52\frac{1}{2}^\circ$ to the west.

The normal on this plane meets the sky in a point having an azimuth of $121\frac{1}{2}^\circ$, and an altitude of $37\frac{1}{3}^\circ$. At the middle of totality the sun had an azimuth of $131^\circ.4$ and an altitude of 54°. Accordingly there is a difference of 10° in azimuth, and 16° in altitude. As regards the rough computation of the direction of the shadow-lines, this error may easily have been made, the more so as the observers were not prepared for an accurate observation of the phenomenon.

Thus it appears, without anticipating more accurate observations on the occasion of late eclipses, that the shadow-lines were situated in planes perpendicular to the sun's rays. They moved *from* the sun.

Singularly enough, neither at Tjilentaf, nor at the Island Lawoengan, was anything of the phenomenon seen. At the island circumstances were very unfavourable, but at Tjilentaf the sky was clear.

CHAPTER X.

PULSATIONS OF LIGHT ON APPROACH OF TOTALITY AND TREMULOUS MOTION OF THIN CRESCENT.

AIRY, ADAMS, LESPIAULT, BURAT, RUMKER, AGUILAR, and BLAKE describe the limbs of the solar crescent as appearing to undulate violently on the approach of totality. AIRY and BLAKE perceived the phenomenon, the one six, and the other eight minutes before the commencement of totality. The other observers either do not mention the time, or speak of the undulations as being visible for only a few seconds before or after totality. RUMKER noted that though the phenomenon was very apparent to the naked eye it was not visible in the telescope.

PIAZZI SMYTH and J. D. SMITH describe a fluctuation or pulsation in the intensity of the light of the sun near to the time of greatest obscuration during the annular eclipse of 1858. RYDHENIUS speaks of undulating red rays thrown out by the sun just before and after totality. And ATTENOUX in 1842 describes undulations seen in the air which appeared to go in the same direction as the wind. Compare also with this the observation of Lady AIRY, given in the chapter on "The Approach of the Moon's Shadow seen at Totality," in which she describes an appearance as of "a streaky shower of smoke or fine dust," which was "perfectly clear" and appeared to sweep "along the valley and northern hills." See also WINNECKE's observation, given in the same chapter, in which he describes "the moon's shadow as approaching like smoke."

Herr Rydhenius. FORSHEM, 24th Sept., 1733.

"Acta Lit. et Scienc. Suec.," iv., p. 61.

Sol lucem penitus amissurus eademque recuperaturus, radios ejaculabat fluctuabundos, instar auroræ borealis, et rutilos.

Just before and after totality, sun threw out red rays which undulated like the aurora.

M. Auguste Attenoux.

SALON,
8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 304.

A few seconds before and after totality distinct undulations were seen in the air moving in the same direction as the wind that was blowing.

Je m'étais transporté, pour mieux observer l'éclipse, sur une petite élévation qui domine la ville; le ciel était serein, et un petit vent nord-ouest (le mistral), assez frais pour la saison, se faisait sentir, lorsque quelques secondes avant la disparition du dernier rayon solaire, je vis très-distinctement, ainsi que la seule personne qui était auprès de moi, une légère ondulation dans l'air qui suivait, autour de nous, la direction du vent. Ce mouvement n'était nullement semblable à celui que produit l'émission de la chaleur sur un corps métallique fortement chauffé, ou pendant une grande journée d'été à midi celui que nous voyons à quelques centimètres au-dessus du sol de la Crau. C'était un mouvement ondulatoire bien distinct, bien apparent, et que je puis comparer à celui qu'aurait eu l'eau exposée au même vent dans un grand bassin, en formant quelques vagues assez allongées, se succédant rapidement les unes aux autres. Ce phénomène s'est reproduit après l'apparition subite du Soleil, et n'a duré que quelques secondes.

Plusieurs personnes à qui je viens de faire part de ce fait s'en sont aperçues comme moi, et nous pouvons dire avec hardiesse maintenant que nous *avons vu passer le vent.*

Sir G. B. Airy.

CHURCH OF THE SUPERGA, NEAR TURIN,
8th July, 1842.

"Monthly Notices," Vol. v., p. 216.

About six minutes before the totality I specially recorded the remark that there was a slight undulation on the limbs, but that the cusps were perfectly sharp.

Prof. J. C. Adams.

FREDERIKSVŒRN,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 103.

As the crescent became very narrow, it seemed to be in a state of violent agitation.

Prof. C. Piazzi Smyth. BRENTWOOD, ESSEX, 15th March 1858.

" Monthly Notices," Vol. xviii., pp. 185-6.

Almost immediately after [the annular eclipse was at its maximum] I perceived a strange fluctuation of the light in the region of illumined cloud, which kept constantly about the sun in a patch about a degree to a degree and a half broad, notwithstanding the rapid passage of the semi-transparent clouds across . . . . I called attention twice, at an interval of some five or seven seconds, to what seemed to me the startling coming forward and going back of the light of the solar crescent and the illuminated mist round about it.

Mr. J. D. Smith. LAYCOCK ABBEY, WILTS, 15th March, 1858.

" Monthly Notices," Vol. xviii., p. 251.

Both my brother and myself were distinctly impressed with the conviction that the withdrawal of light was not continuous but by pulsations, or, as it were, waves of obscuration, the darkness increasing by strokes which sensibly smote the eye, and were repeated distinctly some five or seven times after we had remarked the phenomenon and before the time of greatest obscuration. This did not occur on the return of the light, which came back continuously and without shock or break.

M. Lespiault.
M. Burat. BRIVIESCA, 18th July, 1860.

" Observations sur l'Eclipse Totale du 18 Juillet, 1860," par MM. Lespiault et Burat, p. 3.

Dans les premières secondes qui ont précédé l'obscurité, au moment où les bords des deux astres s'approchaient du premier contact intérieur, une sorte d'indécision s'est manifestée dans l'aspect du petit croissant solaire qui restait visible; la limite intérieure, formée par l'arc de la lune, paraissait irrégulière et tremblante; et le contour extérieur n'était pas aussi net que d'habitude.

A few second before totalit the interior li of the crescei appeared irregular and trembling, an the exterior v not as sharp usual.

Herr Geo. Rümker.

CASTELLON DE LA PLANA,
18th July, 1860.

"Die Totale Sonnenfinsterniss am 18 Juli, 1860." 4to, Hamburg, 1861, p. 6.

Although the disappearing crescent appeared to undulate to the naked eye, it was perfectly motionless in the telescope.

Wenngleich das Verschwinden der letzten Sonnenstrahlen dem blossen Auge ein höchst flimmerndes Schauspiel bot, so geschah dasselbe im Fernrohr mit der grössten Ruhe, ohne die geringste undulirende Bewegung; in den letzten Secunden selbst bot die erlöschende Sichel das ruhigste klarste Bild dar.

Don Antonio Aguilar.

DESIERTO DE LAS PALMAS,
18th July, 1860.

"Astr. Nachr.," Vol. liv., p. 18.

At the disappearance of the sun its limb undulated greatly as if it had been made of a liquid or soft substance.

Al desaparecer el Sol se notó en su limbo una fuerte ondulacion como si se compusiera el disco de una materia líquida ó pastosa.

Mr. F. Blake, Jun.

SHELBYVILLE, KENTUCKY,
7th Aug., 1869.

"United States Coast Survey Report for 1869," Appendix, No. 8, p. 29.

Eight minutes before totality, the limbs of the sun and moon were shaking violently.

CHAPTER XI.

FAINT BRUSHES OF LIGHT FROM THE SOLAR CRESCENT.

THE rays or brushes seen during the earlier partial phases appear in no case to have been persistent, thus:—

1851.	**Hind.**	Seen when the sun was two-thirds covered.	Not visible more than one minute.
	Fearnley.	When sun was more than one-half covered.	Lost whenever the telescope was moved.
1858.	**Branfill.** **Hearn.**	When sun was about three-quarters covered.	Disappeared after 10 minutes.

These rays are in each instance described as springing from the cusps of the crescent, and appear not to have been very conspicuous objects—possibly the "feinen Lichtbogen" seen by FEARNLEY may have been arcs of faint light contiguous to the portion of the moon's limb just outside the sun's disc.

The more conspicuous rays seen in the few minutes preceding or after totality are not always described as springing from the cusps; they are drawn by some of the observers as springing from several points of the limb of the solar crescent. JACOB and CAMPBELL describe the rays as tangential, and stretching in both directions—JACOB as tangential at the northern cusp, and CAMPBELL as tangential to the moon's limb at the centre of the crescent.

GALTON gives in his diagrams at least four rays, one as broad as the whole solar diameter; and LETHBRIDGE and PETLEY describe three rays from the southern half of the crescent.

The rays are in all cases spoken of as straight, except by GOODWIN, who says that they were at first curved in a direction contrary to the curvature of the disappearing crescent, but that they rapidly grew out, becoming straighter as they lengthened. WEYER is the only observer whose

testimony can be ranged under the head of negative evidence, and he does not say that his attention was directed to the phenomenon during the eclipse, or that he looked for the rays during the few minutes before or after totality.

As to the length of the rays; they are described—

1860.	**Atwood.**	As equal in length to the diameter of the moon.
	Galton.	Becoming fainter until they were lost at about $1\frac{1}{2}°$ distance.
1868.	**Campbell.**	Extended beyond each cusp to a distance of $15'$ (therefore the whole length was about $1°$).
1870.	**Brett.**	More than $3'$.

As to their appearance and brightness, they are described—

1847.	**Jacob.**	As a faint ray or brush of light.
1860.	**Buckingham.**	A brush of faint light like the tail of a comet.
	Weiler.	A tuft of rays.
	Jacob.	Long coloured rays like those of inflected light.
	Goodwin.	Small tufts which I could only compare to brushes of electric light.
	Atwood.	A stream of light.
	Galton.	Radiations like sunbeams slanting through a cloud . . . . they were more ghost-like than the rays through a cloud.
1868.	**Campbell.**	A bright line of light . . . . The corona did not appear so bright as the line, the brilliance and whiteness of which was most striking. It was seen through a highly smoked glass.
	Hennessy.	From W. cusp a beam of light pale and straight.
	Ellis.	From E. cusp a corresponding dark band or shadow.
	Anson.	Shadow of darkness.
1869.	**Hough.**	Tails of light.
	Paine.	Brush of light.
1870.	**Lethbridge.** **Petley.**	Rays of light.
	Brett.	A delicate and exquisitely defined little ray or cone of light . . . . its light less intense than that of the cusp, but beautifully defined.
1871.	**Holiday.**	Lines which marked the limits of the advancing tunnel of shadow.

The rays are described as changing in form, or growing in length or distinctness during the time that they were observed by the following observers:—

1847.	Jacob.	At first as a brush from the N. cusp, which soon after extended in both directions.
1860.	Buckingham.	Brush from S. cusp, then from N. cusp, afterwards described as "stronger and extending" with "slight traces at every break or dark space."
	Goodwin.	Tufts from cusps at first curved, but they "rapidly grew out, becoming straighter as they lengthened."
	Galton.	"The appearances varied so rapidly that none of my sketches profess to be accurate."
1870.	Lethbridge. Petley.	"They darted out suddenly one after the other for a certain distance, and after two seconds' interval suddenly prolonged themselves."

The time at which the rays or brushes were first perceived before totality or during which they have been traced after totality, appears to vary from a few seconds to nine minutes. Thus we have—

1847.	Jacob.	Shortly before the annular phase.
1860.	Buckingham.	44 seconds before totality.
	Weiler.	A few seconds before the totality.
	Jacob.	Rather more than four minutes before.
	Atwood.	Shortly after totality, and continuing for some minutes.
	Galton.	Three or four minutes after totality had passed. Mr. ATWOOD called attention . . . . I examined them for three or four minutes.
1868.	Campbell.	Closely before totality.
	Hennessy. Ellis.	About nine minutes before totality.
	Anson.	Five minutes before totality.
1869.	Hough.	Time not mentioned.
	Paine.	About five minutes before the second contact.
1870.	Lethbridge. Petley.	Perhaps three minutes before totality.
	Brett.	About five minutes before totality.
1871.	Tennant.	Very shortly before totality.
	Holiday.	Before totality, when Baily's beads appeared. The time they remained visible after totality is not given.

HOLIDAY and ANSON appear to concur with STOKES * in thinking that the rays mark the limits of the advancing shadow in the air, yet ANSON draws a diagram representing a brush with two defined edges, and other

* See note by Prof. Stokes given on pp. 69—70.

observers speak of the rays as having defined boundaries, and even estimate the angle between them, thus:—

1860.	**Galton.**	The radiations were perfectly defined . . . . they were of even brightness through their length, and faded rapidly at their extremities.
1860.	**Hennessy.**	A beam of light, the rays diverging at a small angle.
1870.	**Brett.**	A delicate and exquisitely defined little ray or cone . . . . as beautifully defined as anything I ever saw in my life . . . . angle at the apex was small, not more than 5°.

GALTON appears to be the only observer who experimented as to whether the rays were visible when the solar crescent was hidden from view.

Captain Jacob. BOMBAY, 9th Oct., 1847.

"Monthly Notices," Vol. viii., p. 27.

Shortly before the annular phase, a faint ray or brush of light was seen issuing from the sun's northern cusp, which soon after extended in both directions as a tangent to the sun's limb: nothing of the kind was visible at the other cusp.

Mr. Hind. RŒVELSBERG, NEAR ENGELHOLM, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 82.

When about two-thirds of the sun's disc were covered, I thought I could distinguish two faint rays of light, shooting off as tangents to the moon's limb at the cusps, and on removing my eye from the telescope for a few seconds, and again applying it, the same appearance presented itself, but was not visible more than one minute.

Prof. Fearnley. RIXHÖFT, 28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 237.

Faint light occasionally seen extending beyond the upper cusp; lost when the telescope was moved.

Mehrmals sah ich, nachdem die Sonne schon mehr als halb verfinstert war, von der oberen Hörnerspitze einen ganz kurzen, feinen Lichtbogen, scheinbar in der Verlängerung der Mondperipherie, ausgehen. Es muss aber nur am Fernrohre gelegen haben, da ich jedesmal die Erscheinung durch veränderte Lage des Bildes zum Verschwinden bringen konnte.

Mr. J. Buckingham. CAMMESA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

At 2 h. 57 m. 58 s., [forty-four seconds before totality,] a brush of faint light like the tail of a comet shot out beyond the southernmost point of the crescent.

2 h. 58 m. 19 s., the northern similarly, yet stronger; evidently the corona. 2 h. 58 m. 38 s., yet stronger, and extending; slight traces at every break or dark space.

3 h. 2 m. 59 s., the thin crescent had a detached piece at its northern horn with a faint brush of the corona next to it.

Mr. Wm. Wray. CAMMESA, NEAR AGUILAR, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

I first noticed the corona at the southern cusp, very soon after the formation of the first detached point of light. It was then very faint and narrow.

Mr. C. Weiler. HILL OF SANTA MARINA, 3 MILES S.W. OF POBES, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

A few seconds before the totality the remaining part of the sun blended itself in a tuft of rays appearing like the rays of a rising star in a damp atmosphere.

Capt. W. S. Jacob. PEÑA CERRADA, SIERRA DE TOLOÑO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

At 2 h. 46 m., [rather more than four minutes before the sun disappeared,] long coloured rays, like those of inflected light, were seen issuing from the thin crescent of the sun.

Prof. G. D. E. Weyer. HILL OF SANTA LUCIA, VITORIA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

Bunches of light at the cusps were not perceived either by myself or by others, as far as I know, at our station.

The Rev. H. A. Goodwin. ALI, NEAR VITORIA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The corona commenced in the most striking manner at the cusps of the disappearing sun in the form of small tufts which I could only compare to brushes of electric light, at first curved, in a direction contrary to the curvature of the sun's disappearing crescent. These brushes rapidly grew

out, becoming straighter as they lengthened, the upper one approaching very near to a long straight beam, which struck out from a point somewhat easterly on the sun's limb. The corona itself * was far from being regular even at the midst of totality.

* It does not appear from Mr. Goodwin's *description* whether he means that the tangential rays were only visible before totality, or whether they formed part of and merged into the coronal structure. But his remark that "even in the midst of totality the corona *itself* was far from

The Rev. H. S. Atwood. La Guardia, near Logroño,
18th July, 1860.

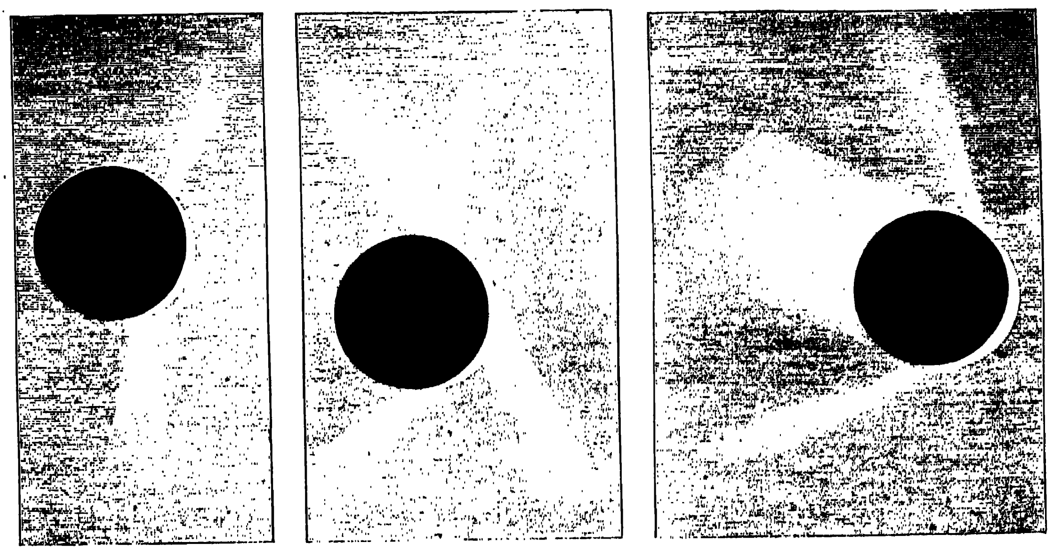
MS. Reports of the Himalaya Expedition.

Shortly after totality and continuing for some minutes, there was a singular stream of light proceeding from the cusps of the sun's crescent, the lower one especially, equal in length to the diameter of the moon, and of a character resembling the electric light.

Mr. Galton. La Guardia, near Logroño,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

Three or four minutes after totality had passed, and the corona dis-



3h. 11m. 3h. $12\frac{1}{2}$m. 3h. 13m.

appeared, one of our party (Mr. Atwood) called attention to radiations like sunbeams slanting through a cloud striking off from the sun. I observed these in four different ways, viz. :—

regular," seems to imply that the rays observed at first did not persist. We have given the above drawing as Mr. Goodwin seems to have embodied in it the curved tufts of light seen before totality as well as the corona.

Prof. G. D. E. Weyer. HILL OF SANTA LUCIA, VITORIA, 18th July, 1860.

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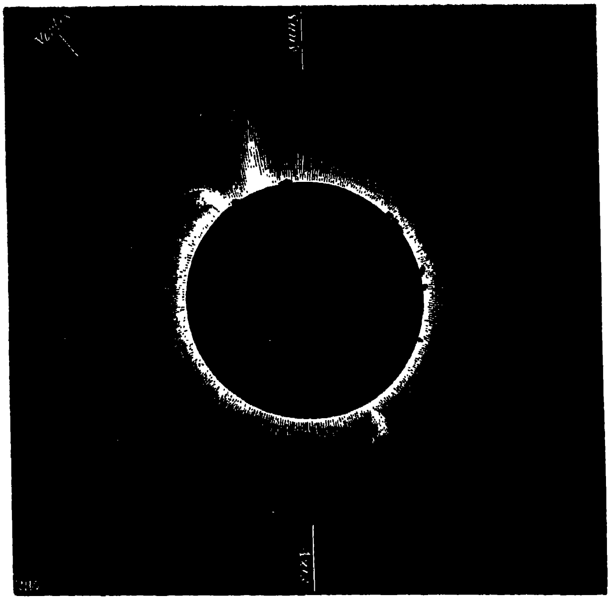

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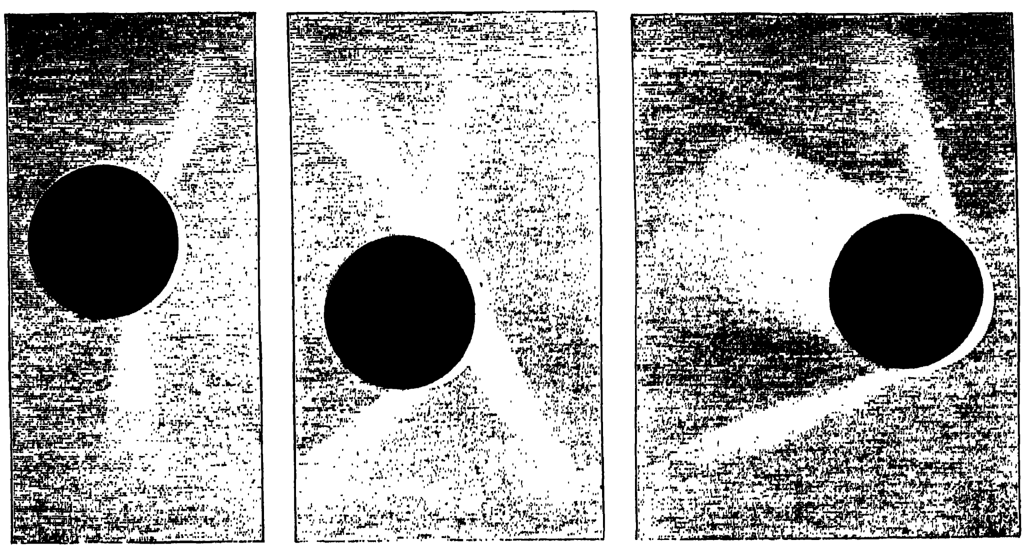

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regular," seems to imply that the rays observed at first did not persist. We have given the above drawing as Mr. Goodwin seems to have embodied in it the curved tufts of light seen before totality as well as the corona.

By direct vision.

Holding up my finger so as to blot out the sun.

By a telescope of very low power pointed so as to include the sun.

With the same pointed so as to exclude the sun.

There was no mistake about the radiations, for in every case they were perfectly defined and stretched away, becoming fainter until they were lost at about $1\frac{1}{2}^\circ$ distance from the discs of the sun and moon. I examined them for three or four minutes, but the appearances varied so rapidly that none of my sketches profess to be accurate. At some moments they appeared more marked than at others. The outer rays were the most defined; they were of even brightness through their length, and faded rapidly at their extremities; they were more ghost-like than the rays through a cloud.

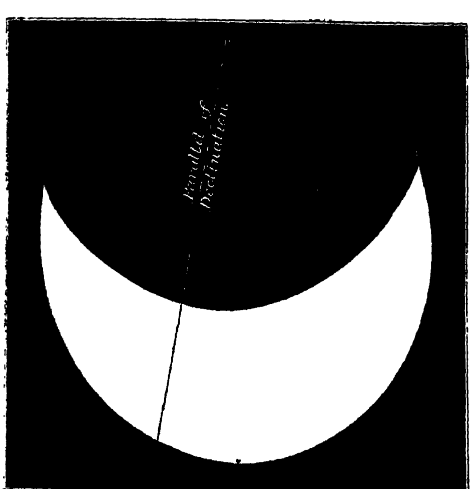
Captain Branfill. GUNTOOR,
Major Hearn. 18th Aug., 1868.

"Memoirs of the Royal Astronomical Society," Vol. xxxvii., p. 24.

When about three quarters of the sun's diameter (by estimation) was obscured, I observed faintly luminous lines beyond the cusps, and about half-way between the limbs of the sun and moon prolonged.

[The annexed drawing was made by Col. Tennant, and was seen and approved of by Capt. Branfill].

The lines were also seen by Major Hearn; they had disappeared ten minutes after.



Lieut. Campbell. NEAR JAMKANDI,
18th Aug., 1868.

"Proceedings of the Royal Society," Nov., 1868, p. 122.

Closely before totality a bright line of light appeared to shoot out at a tangent to the moon's limb at its centre, as if running across the bright

crescent of the sun (though of course not visible against the superior light), and extended beyond each cusp to a distance nearly, if not quite, 15′. [Note by Lieut. HERSCHEL: "The sketch in the margin represents Lieut. CAMPBELL'S meaning as ascertained orally."]

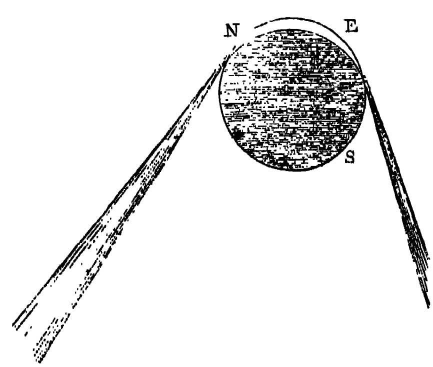
The corona became visible immediately after, between the dark limb of the moon and the bright line. The corona did not appear so bright as the line, the brilliance and whiteness of which was most striking. This was seen through a highly smoked glass.

At this period, probably not more than 3 to 5 seconds before totality ensued, a thick cloud shut out everything.

Governor Pope Hennessey. BARRAM POINT, BORNEO,
Mr. Ellis. 18th Aug., 1868.

"Proceedings of the Royal Society," Recess, 1868, p. 84.

[About nine minutes before the total eclipse,] a long beam of light, pale and quite straight, the rays diverging at a small angle, shot out from the westerly corner of the sun's crescent. At the same time Mr. Ellis noticed a corresponding dark band or shadow, shooting down from the east corner of the crescent.



[Note by Prof. Stokes, p. 88. id.] The slender beams of light or shade shooting out from the horns of the crescent would seem to admit of easy explanation, supposing them to have been of the nature of sunbeams, depending upon the illumination of the atmosphere of the earth by the sun's rays.

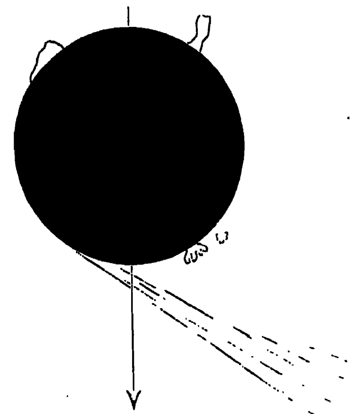
The perfect shadow, or umbra, would be a cone circumscribing both sun and moon, and having its vertex far below the observer's horizon. Within this cone there would be no illumination of the atmosphere, but outside it a portion of the sun's rays would be scattered in their progress through the air, giving rise to a faint illumination. When the total phase

drew near, the nearer surface of the shadow would be at no great distance from the observer; the further surface would be remote.

Attend in the first instance to some one plane passing through the eye and cutting the shadow transversely, and in this plane draw a straight line through the eye, touching the section of the cone which bounds the shadow; and then imagine other lines drawn from the eye a little inside and outside this. In the former case the greater part of the line, while it lay within the lower regions of the atmosphere, would be in shadow, the only part in sunshine being that reaching from the eye to the nearer surface of the shadow; but in the latter case the line would be in sunshine all along. In the direction of the former line, therefore, there would be but little illumination arising from scattered light, while in the direction of the latter the illumination would, comparatively speaking, be considerable. In crossing the tangent there would be a rapid change of illumination. Now pass on to three dimensions. Instead of a tangent line we have a tangent plane, and there will of course be two such planes, touching the two sides of the cone respectively. Each of these will be projected on the visual sphere into a great circle, a common tangent to the two small circles, which are the projections of the sun and moon. In crossing either of these there will be a rapid change of illumination (feeble though it be at best), which will be noticed.* According as the observer mentally regards darkness as the rule and illumination as the feature, or illumination as the rule and darkness as the feature, he will describe what he sees as a *beam* or a *shadow*. The direction of these beams or shadows given by theory, as just explained, agrees very well with the drawing sent by Governor Hennessy, which does not represent the left-hand beam so distinctly divided as it appears in the woodcut.

* We should expect the greatest amount of light to be scattered in the lower portions of the earth's atmosphere—and probably no very observable quantity at heights exceeding forty miles—two or three minutes before totality lines drawn from the observer's eye as tangents to the moon's shadow, in the apparent neighbourhood of the sun and moon, would meet with the cone of totality at an enormous altitude above the earth, and the nearer to the sun's apparent place, the greater would be the altitude; we should therefore expect the distinctness of the rays from the horns of the crescent to increase with the distance from the sun. But the reverse of this seems to be the case; the rays are brightest in the neighbourhood of the cusps.

Lieut. Anson. MANTAWALU KIKI, CELEBES,
19th Aug., 1868.



MS. Observations of the 1868 Eclipse.

Rough diagram to illustrate Lieut. Anson's observation of the "Shadow of darkness coming from the westward." His observation was made five minutes before totality.

Prof. G. W. Hough. MATTOON, ILLINOIS,
7th Aug., 1869.

"The Total Eclipse of Aug. 7th, 1869, by Prof. G. W. Hough." Albany, 8vo, 1870. "Journal of the Franklin Institute," Jan., 1870, p. 61.

When the sun was about half eclipsed, a red band of light, etc. . . . . Later, during the progress of the phenomenon, tails of light were seen projecting out, tangent to the moon's limb, and extending 15° or 20° along the edge.

Mr. R. T. Paine. BOONESBORO, BOONE COUNTY, IOWA,
7th Aug., 1869.

"Monthly Notices," Vol. xxx., p. 2.

About five minutes before the second [contact], a brush of light descended from the upper crescent of the sun.

Capt. Lethbridge.
Mr. G. N. Petley. GIBRALTAR,
21st Dec., 1873.

MS. Reports of the 1870 Expedition.

Just before the totality (perhaps three minutes) we observed three bright rays of light shoot out from the S.W. quarter of the sun. They

darted out suddenly one after the other for a certain distance, and after two seconds' interval suddenly prolonged themselves until they had the appearance shown in figure A; and after an interval of thirty seconds

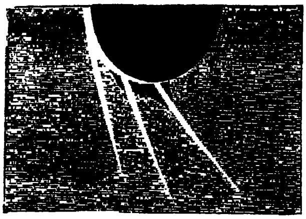


FIG. A.

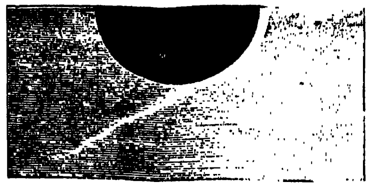


FIG. B.

they disappeared and did not appear again until after the totality, when one ray darted out from the south quarter as shown in figure B.

Mr. John Brett. AUGUSTA, 22nd Dec., 1870.

"Monthly Notices," Vol. xxxi., pp. 164-65.

About five minutes before totality I went to the side of the Observatory . . . . I returned to the telescope without delay, removed the solar eye-piece and introduced the Kellner, power 100, with dark glass, to take a last look at the cusps before introducing the large field eye-piece with which I proposed to examine the corona. I now beheld a beautiful sight: a delicate and exquisitely defined little ray or cone of light emanating from the south cusp in a direction tangential to the moon's limb. Its length was not more than 3′; possibly something less. Its light was less intense than that of the cusp, but as beautifully defined as anything I ever saw in my life. Its termination at the weak end or base of the cone was clearly visible and not diffused indefinitely, and the angle at the apex was small, not more than 5° . . . .

Having examined this for a few seconds, I brought the north cusp into the field and found a similar ray there, but somewhat smaller.

Lieut. Col. J. F. Tennant. DODABETTA, NEAR OOTACAMUND, 12th Dec., 1871.

Report by Col. Tennant on Observations, etc., . . . p. 4. Printed by the Government of India.

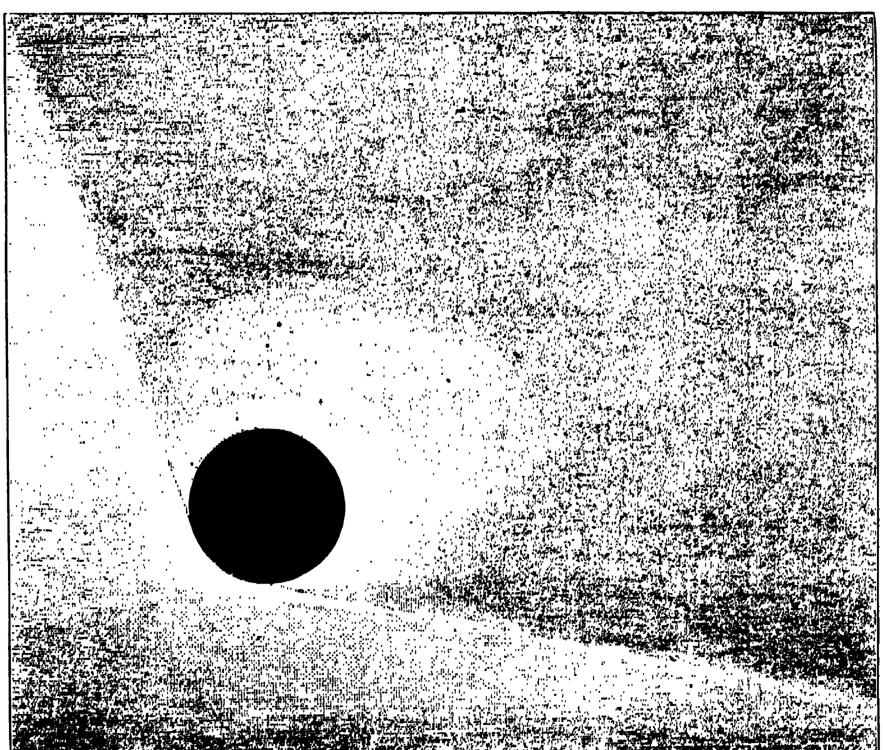
I had intended to have examined those remarkable prolongations of

the cusps which frequently appear to be within the moon's limb, and had hoped that they might be submitted to the spectroscope. I did not however see any signs of these till very shortly before totality, when the cusp was already extremely fine.

Mr. H. Holiday. RESIDENCY BUNGALOW, POODOOCOTTAH, 12th Dec., 1871.

MS. Reports of the 1871 Expedition.

When Baily's beads appeared I removed the dark glass, but replaced it instantly, the light being still so brilliant that I feared to spoil my eye for after observations if I looked then; but that momentary glance showed me the two great lines which marked the limits of the advancing tunnel of shadow . . . . . on the reappearance of the edge of the sun the two long lines were thrown off, giving an inversion of my first sketch. This time I was not afraid to watch it, and I have been able to make a drawing of that final phase.



CHAPTER XII.

PARHELIA AND RAYS SEEN JUST BEFORE TOTALITY.

THE appearances described in the two following extracts seem to have been of the same ghost-like character with the rays and brushes of light described in the last chapter. Though more complicated in form they appear, like the rays and brushes, to have been symmetrically situated with regard to the solar crescent, and to have disappeared on the commencement of totality. The rays seen by ARNDT, like those observed by GALTON, were visible in a telescope as well as with the naked eye. The "Strahlenfäden" described by Frau MÄDLER are spoken of as appearing to be in swift rotatory motion.

Frau Maedler.

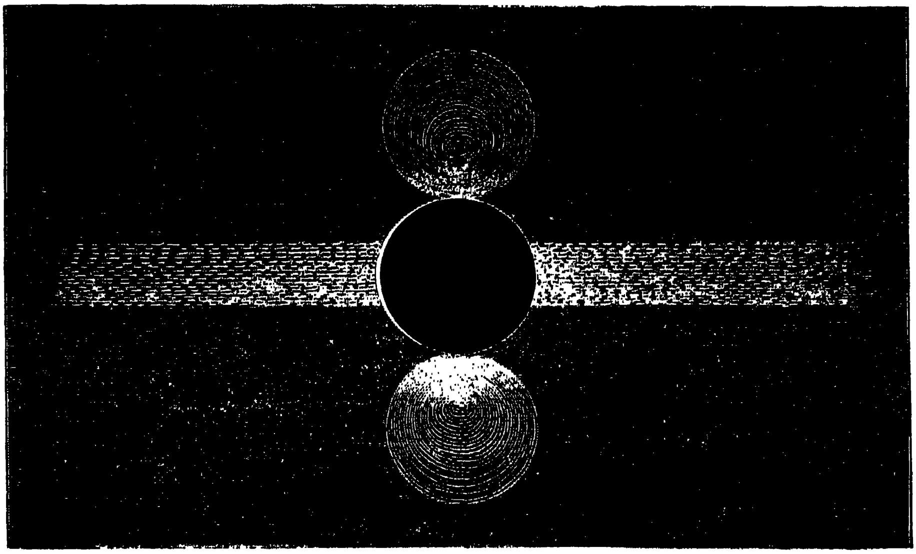
VITORIA,
18th July, 1860.

"Ueber Totale Sonnenfinsternisse." Dr. von Mädler. (p. 24.)

Some 30 s. to 40 s. before totality from the E. and W. limb of the sun streamed two rays of yellowish-white light, and N. and S. were two similarly coloured masses of light which appeared like an unbroken thread, turning rapidly round from left to right.

Bei dieser Finsterniss hatte ich besonders die Färbung der Wolken näher und entferntner von der Sonne, so wie der Bergesgipfel und andrer irdischen Gegenstände zu beobachten mir vorgenommen. Zu diesem Zweck liess ich mein Auge ganz unbewaffnet, und nur die Zu- und Abnahme der Finsterniss betrachtete ich mittelst eines geschwärzten Glases. Kurz vor dem Eintritt der Totalität—etwa 30—40 Sekunden—bemerkte ich mit blossem Auge rings um die fast verdunkelte Sonne eine Lichterscheinung die vom herrlichsten Effect war, und die mehrere Personen, aber nur mit unbewaffnetem Auge, gleich mir, beobachtet haben. Vom östlichen und westlichen Sonnenrande strömten zitternde intermittirende Strahlen vom schönsten gelblich-weissen Lichte aus, die ich mit Reihen länglicher Perlen, jede von der andern durch einen kleinen Zwischenraum getrennt, vergleichen

möchte, und die sich in zitternder Bewegung befanden. Zu gleicher Zeit sah ich über und unter der Sonne im Norden und Süden gleichfarbige nicht unterbrochene Strahlenfäden, die sich vom Lichtrand in schnellster Bewegung von links nach rechts drehten und mit den oben beschriebenen nach Ost und West laufenden Strahlen um die Sonne eine Lichtfigur bildeten. Sie hatte einen weit grösseren aber nicht so bestimmt erscheinenden Umfang



als die Corona, und verschwand augenblicklich, als sich diese mit dem Eintritt der Totalität dem Auge darstellte.

Um ganz den Eindruck zu beschreiben, den der Uebergang zur völligen Sonnenfinsterniss auf mich machte, möchte ich sagen: es erschien, als ob sich ein obiges Strahlensystem als Corona um die Sonne zusammenzog, so rasch folgten sich die beiden Erscheinungen.

Herr Arndt. CASTELLON DE LA PLANA, 18th July, 1860.

"Ueber Totale Sonnenfinsternisse." Dr. von Mädler. (p. 39.)

Er sah mit unbewaffnetem Auge kurz vor Beginn der totalen Verfinsterung zwei weisse Strahlenbüschel, welche in der Richtung der Radien vom Doppelgestirn ausgingen und sich mit immer abnehmender Lichtstärke um

Shortly before the beginning of totality two white rays, about 7′ broad, seen stretching E and W. to a distance

of about 1° from the moon's limb. With a telescope two other smaller rays at right angles were seen.

mehr als zwei Durchmesser von dessen Peripherie entfernte Büschel erstreckten sich von Ost nach West, und ihre Basis nah 30° Mondumfangs ein. In einem kleinen 6 mal vergrössernden hol Fernrohr sah er ferner senkrecht auf jenen Büscheln zwei Bündel Strahlen von der Breite des Monddurchmessers, die sich ebe hinweg erstreckten und nach Nord und Süd gerichtet waren.

CHAPTER XIII.

BRUSHES OF LIGHT ALONG THE EDGE OF THE DISAPPEARING CRESCENT.

It will be seen from the next chapter that the corona first makes its appearance on the side of the dark moon opposite to the disappearing crescent, but the brushes of light observed by Buckingham, Wray, Plantamour, Pillay, and Annappa were on the same side, along the convex limb of the disappearing crescent. Buckingham and Wray describe how the brushes sprang from the dark spaces between Baily's beads, and Wray mentions a faint light extending inwards for about 4′ over the dark moon, and lasting for some two or three seconds of time. Plantamour seems confident that the appearance of jets of flame seen by him was due to his first view of the chromosphere.

Searle and Langley do not describe on what part of the moon's limb the brushes first made their appearance, but their descriptions are in other respects so similar to those of the above mentioned observers, that we have thought it best to include their observations in the present chapter.

The time at which the brushes have been seen before totality varies from nearly two minutes to a few seconds, thus:—

1860.	**Buckingham.**	Four seconds before totality.	Brushes of light from every break or dark space in the crescent.
	Wray.	Nearly two minutes before totality and after totality.	The corona flashed out from each dark bridge as it formed.
	Plantamour.	Three seconds before.	Flames or jets of vivid red light.
1869.	**Searle.**	About one minute before.	Brushes of light perpendicular to limb.
	Langley.	Two seconds before.	Like tongues of pale flame.
1871.	**Pillay.** **Annappa.**	Time not mentioned.	No description.

Mr. J. Buckingham. CAMMESA, 18th July, 1860.

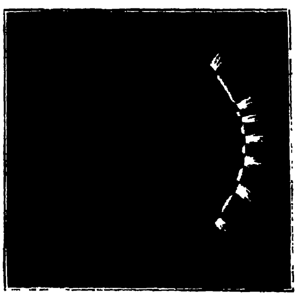
MS. Reports of the Himalaya Expedition.

Four seconds before the total immersion there were similar traces [*i.e.* brushes of light like the tails of comets] from every break or dark space in the crescent.

Mr. Wm. Wray. CAMMESA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.*

I first noticed the corona at the southern cusp very soon after the formation of the first detached point of light. It was then very faint and narrow, and as the crescent broke up, it flashed out from each dark



bridge as it was formed, and was thus visible in portions, for nearly two minutes before totality. No trace of it could be perceived about those regions of the moon beyond which the direct light of the sun still lingered.

At the instant of the formation of the dark bridges in the crescent by the lunar mountains there appeared, for about two or three seconds of time, a faint irradiation extending inwards from the angles of the dark bridges towards the centre about $\frac{1}{8}$th of a diameter in length; it speedily disappeared, but was seen very definitely to be a constant attendant on the formation of a dark bridge. It was not produced by the telescope.

Whilst gazing at the corona at the end of totality several detached portions of the newly forming crescent became visible, first as small points and then increasing as the moon advanced into irregularly shaped fragments; and I noticed that on the instant these points of direct sunlight became visible the corona vanished at such places, though it continued to shine with great splendour about elevated regions of the moon which still shut out the direct sunlight.

* The woodcut is taken from a lithographic plate given by Prof. Weyer, in his account of the eclipse published at Kiel. A similar woodcut appeared in the "Illustrated London News."

Prof. Plantamour. CASTELLON DE LA PLANA,
18th July, 1860.

"Observation de l'Eclipse Totale de Soleil du 18 Juillet, 1860, par M. le professeur E. Plantamour." Genève, 1860.

(p. 5.) Trente secondes environ avant le commencement de l'éclipse totale, et l'obscurité étant déjà très-appréciable, j'ai voulu essayer d'enlever le verre obscur, mais la lumière était encore trop éblouissante; j'ai dû le remettre pour ne l'enlever que dans les dernières secondes qui ont précédé la disparition du soleil. A ce moment, c'est-à-dire trois secondes environ avant cette disparition, lorsqu'on ne voyait plus qu'un très-petit segment du bord du soleil, sous la forme d'une scie lumineuse à travers les anfractuosités du disque de la lune, mon attention a été attirée sur les flammes, ou jets de lumière du rouge le plus vif, qui jaillissaient sur toute la partie orientale du bord de la lune, là où son disque venait le déborder sur celui du soleil.

Three seconds before totality jets of red light seen all along the E. limb of the moon, and similarly after totality on the W. limb.

Ces jets de lumière étaient de longueur très-inégale; les* uns, les plus courts, ont disparu au bout de peu d'instants; les plus grands, ceux auxquels on a donné le nom de protubérances, sont restés visibles pendant une partie plus ou moins longue de la durée de l'éclipse totale, mais avec des modifications très-grandes dans leur apparence. A leur première apparition au bord oriental de la lune, au moment de l'immersion, et dans les deux ou trois secondes qui précèdent et qui suivent cet instant, et de même, dans un ordre inverse, près du bord occidental de la lune, dans les deux ou trois secondes qui précèdent et qui suivent l'émersion du disque du soleil, il me semble que le terme de jets de lumière rendrait mieux compte de leur apparence que celui de protubérances.

Mr. G. M. Searle. SHELBYVILLE,
7th Aug., 1869.

"United States Coast Survey Report for 1869;" Appendix No. 8, p. 22.

About a minute or so before the totality I saw the complete disc of the moon, with the incipient corona in the form of short brushes of light

* On pourrait les comparer aux petits jets de gaz dont on se sert dans les illuminations, et que l'on obtient en perçant un conduit de petits trous très-rapprochés.

perpendicular to the limb, and about two or three minutes in length, apparently equally distributed. I did not notice whether these increased in length before the total obscuration, and am not sure whether I saw them with the naked eye or opera-glass.

Prof. S. P. Langley. JEREZ DE LA FRONTERA, 22nd Dec., 1870.

"United States Coast Survey Report for 1870;" Appendix 16.

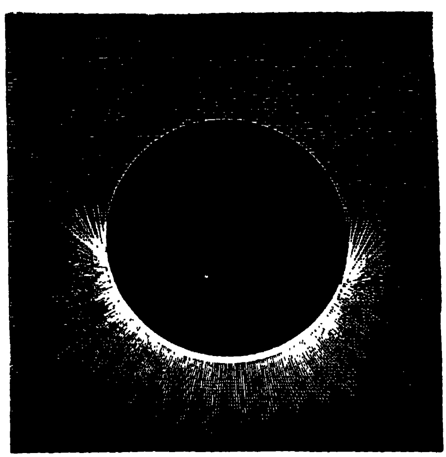
(p. 49.) The first appearance of the corona was at least two seconds before totality. Its outline was very irregular, the edge not so much serrated as looking like tongues of pale flame. I may compare it to the low flame of burning grass in a distant prairie fire.

(p. 48.) *After* seeing the corona, the so-called "Baily's beads" were formed and disappeared.

Mr. T. Gopalkristnah Pillay. MANDALORE,
Mr. O. Annappa. 12th Dec., 1871.

MS. Reports of the 1871 Expedition.

The figure represents the rays seen before totality. Similar rays were also seen after totality.



CHAPTER XIV.

THE CORONA SEEN BEFORE AND AFTER TOTALITY.

THE corona is in all cases described as becoming visible on the side of the dark moon opposite to the disappearing crescent. OOM speaks of it as *suddenly* forming round the moon as a ring of light about 3′ broad, fading towards the outside, at first concentric with the moon, but afterwards with excrescences. JACOB describes it as "flashing out suddenly" and spreading "almost instantly round the circumference like the opening of a fan;" and DAWSON describes the rays as suddenly springing up along the arc of the black moon. On the other hand, BECK says that the corona seemed not so much to be formed, as to be rendered visible by the diminution of light; and of the observers who watched the disappearance of the corona after totality, THOMPSON says that it was gradually rendered invisible, and LOCKYER that it faded away in the rapidly increasing sunlight. It should be noticed, that none of the three observers who describe the *sudden* appearance of the corona, mention that they had previously been looking for it in vain.

BECK, POLE, and SECCHI describe the traces of the corona, seen by them while the solar crescent was visible, as being so bright as to be easily seen through a dark glass.

On the other hand, POGSON states that he saw no trace of the corona after totality, though he looked for it both with the naked eye and with the telescope.

The time during which the corona has been perceived before or after the total phase varies from a few seconds to as much as twelve minutes.

1842	**Petit.**	Five to six seconds before.
	Roche.	The same.
	Largeteau.	Four to five seconds before.

	Valz.	Some seconds after.	
1851	**Bond.**	Half a minute after.	On the side opposite the exposed limb.
	Hind.	Five seconds after.	On the western side.
	Billerbeck.	Several seconds before.	Around the moon.
1860	**Petit.**	Twelve minutes before.	Around the sun.
	W. Beck.	About a second before.	Visible through a lightly shaded glass on the side *farthest from the sun.*
	Winnecke.	One and a half minutes before.	Corona partly formed.
	Oom.	About one minute before and after.	Formed round the moon as a ring of faint light about 3′ broad. After twenty seconds excrescences were seen upon the ring, and it afterwards divided into two zones.
	Grant.	No time mentioned.	So bright that it might certainly have been seen half a minute earlier.
	Jacob.	Ten seconds before, twelve seconds after.	Corona flashed out suddenly on W. side, and spread round the circumference like the opening of a fan.
	Perry.	One minute twenty seconds before.	On N.W. side (query through dark glass).
	Pole.	One minute thirty seconds after.	Seen through a telescope with a dark glass until hidden by a cloud.
	Thompson.	No time mentioned.	Gradually rendered invisible.
	Wallenberg.	Ten seconds after.	Corona and rays still visible.
	Feilitzsch.	Twenty seconds before.	
	G. Rumker.	One and a half minutes before.	Yellow flamelike rays seen crossing one another.
	Secchi.	No time mentioned, before.	Corona seen through faint dark glass.
	Bulard.	No time mentioned, before.	On side opposite to crescent.
1868	**Pogson.**		Corona not seen after the first flash of returning sunlight.
1870	**Hudson.**	About three-quarters of a minute after.	
1871	**Lockyer.**	Nearly three minutes after.	Coronal structure continued to be seen through telescope.
	Dawson.	No time mentioned, before.	Corona suddenly sprang up on the side opposite to crescent, longest in the centre.

M. Arago.

8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 338.

A Montpellier, M. PETIT aperçut l'auréole blanchâtre, 5 à 6 secondes avant la disparition complète du Soleil.

M. Petit saw the whitish corona 5 s. or 6 s. before totality. M. Roche the same. M. Largeteau 4 s. or 5 s. and M. Valz for some seconds after totality.

M. ROCHE, jeune observateur très-instruit, fit la même remarque.

A Solon, où M. LARGETEAU s'était rendu, la couronne devint visible 4 à 5 secondes *avant* le moment de l'éclipse totale.

M. VALZ m'a écrit de Marseille, que la couronne était encore visible *quelques secondes après* la réapparition du Soleil.

Mr. G. P. Bond. LILLA EDET, 28th July, 1851.

" Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 98.

The corona continued to be visible to the naked eye, at least half a minute after the reappearance of sunlight, on the side opposite to the exposed limb.

Mr. Hind. RŒVELSBERG, NEAR ENGELHOLM, 28th July, 1851.

" Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 83.

The corona was visible *on the western side* at least five seconds after the reappearance of the sun.

Herr A. Billerbeck. RASTENBURG, 28th July, 1851.

" Beobachtung der Totalen Sonnenfinsterniss." Schmidt, 1852.

(p. 6.) Noch ziemlich viele Secunden vor dem Verschwinden des letzten Sonnenstrahls sah BILLERBECK die Corona den Mond umgeben; ehe noch die Totalität eintrat.

The corona seen around the moon for several seconds before totality.

M. F. Petit. BRIVIESCA, 18th July, 1860.

" Astr. Nachr.," Vol. liv., p. 78.

J'ai commencé à apercevoir l'auréole autour du soleil 12 minutes avant le premier moment de l'obscurité, et que cette auréole soutendait alors un angle de 3 minutes et quelques secondes.

Corona seen about the sun with an extension of more than 3' for 12 m. before totality.

Mr. W. Beck. MIRANDA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

For some seconds before the sun was totally hidden, the corona was visible through a lightly shaded glass. It appeared on the side farthest from the sun, and seemed not so much to be formed as to be rendered visible by the diminution of light.

Dr. Winnecke. HILL OF SANTA MARINA 3 MILES FROM POBES, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

One minute and a half before the computed beginning of totality, I distinctly saw the corona partly formed.

Lieut. F. A. Oom. ALTO D'URBANEJA, NEAR POBES, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

At 2 h. 48 m. 23 s.,* I suddenly saw the corona formed round the moon as a ring of faint milk-white light fading towards its outside. Its breadth was then of about 3′. Though this ring was extremely faint near the still visible part of the moon's disc, I judged it as being concentric with the moon. Its dimensions and brightness increased by and by. About 20 seconds after the moment when I first saw it the outline, formerly circular, had some excrescences. Some few instants afterwards I saw the corona divided into two zones: the inner one, brighter than the other, looked like a narrow line of uniform light surrounding the moon, the exterior decreased in brightness from the inside to the outside. Immediately after having seen this division of the corona I saw several rays corresponding to the places where the excrescences had been seen, and starting from the inner zone to which they seemed to belong. Soon after having remarked these last appearances the sun disappeared . . . .

After the total obscuration at the reappearance of the sun, the corona diminished suddenly in dimensions and light, but it still maintained for a certain time its general form and structure. And the last traces did not disappear on the following side of the moon till 2 h. 52 m. 59 s.

* About one minute before the beginning of totality.

Prof. Grant. SIERRA DE TOLOÑO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

Upon looking at the sun I was astonished to find that the corona was already visible to the naked eye. It was so bright that I feel convinced it might have been similarly seen half a minute earlier.

Capt. W. S. Jacob. PEÑA CERRADA, SIERRA DE TOLOÑO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

[Ten seconds before the sun disappeared] the corona flashed out suddenly on the west side of the moon, and spread almost instantly round the circumference like the opening of a fan.

At the end of totality the corona was visible for about twelve seconds after the reappearance of the first trace of sunlight.

Mr. J. G. Perry. HILL OF LA CANTABRIA, NEAR LOGROÑO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

I first observed the corona faintly on the north-west side of the moon one minute and twenty seconds before the entire disappearance of the sun's light. At that time the remaining crescent of the sun could not be viewed through the telescope without the protection of the dark prism.

Prof. Wm. Pole. HILL OF LA CANTABRIA, NEAR LOGROÑO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

On looking into the telescope after the reappearance of the sun, I saw the corona still remaining on the east side,—together with a prominence. They were so distinct that I thought it desirable to continue to observe them, and I was much surprised at the pertinacity, if I may so express it, with which they continued visible.

The sun's crescent soon became so dazzling that I was obliged to use a dark glass, but notwithstanding this, the corona and prominence continued distinctly visible through it, until a cloud shut out the view, at

according to my calculations, a minute and a half after the reappearance of the sun, and I am convinced that but for the cloud I should have seen both the corona and prominence much longer.

Rev. R. A. Thompson. TUDELA, 18th July, 1860.

"The English Churchman," 26th July, 1860.

I observed intently the disappearance of the corona, and can say with confidence that it did not disappear, but was gradually rendered invisible by the increasing intensity of the sun's light. I could perceive it gradually diminishing in breadth till I could no longer observe the sun without protection to the eyes.

Dr. Carl von Wallenberg. VALENCIA, 18th July, 1860.

"Astr. Nachr.," Vol. liv., p. 70.

The corona and its rays visible about 10 s. after totality.

Etwa zehn Secunden nach dem Wiedererscheinen der Sonne war für einen Augenblick die Corona mit ihren Strahlen noch sichtbar, verschwand jedoch gleich darauf.

Freiherr von Feilitzsch. CASTELLON DE LA PLANA, 18th July, 1860.

"Ueber Totale Sonnenfinsternisse." Dr. von Mädler. (p. 39.)

Corona visible about 20 s. before totality.

Die Krone, etwa 20 Sek. vor dem Verschwinden der Sonne, sichtbar war, von milchweisser Farbe, verlief allmählich in das umgebende Dunkel.

Herr Geo. Rumker. CASTELLON DE LA PLANA, 18th July, 1860.

"Die Totale Sonnenfinsterniss am 18 Juli, 1860." 4to, Hamburg, 1861.

Corona and its details seen 1½ m. before totality.

(p. 6.) Die Corona hatte sich wohl schon anderthalb Minuten vor dem Verschwinden der Sonne gebildet, und die ganze Mondscheibe war jetzt sichtbar.

Die von allen Seiten hervorschiessenden gelblichen flammenartigen Strahlen schienen sich unter einander zu verbinden, zu verwirren und sich

zu kräuseln, während der noch sichtbare Theil der Sonne, wie ein Lichtmeer quellend, hervorzuragen und am Mondrande auszutreten schien.

Padre A. Secchi. DESIERTO DE LAS PALMAS,
18th July, 1860.

"Comptes Rendus," li., p. 157.

"L'éclipse s'approchant d'être complète, j'ôtai tous les verres fixes de couleur et je suivis le soleil avec un verre tenu à la main. C'était un excellent verre à teinte neutre de M. LEREBOURS, à lumière graduée, dont la partie faible est très-délicate. On voyait déjà le mince croissant se briser en plusieurs parties près des cornés qui restaient encore très-nettes, et la couronne commençait déjà à se montrer très-bien, même avec le verre obscur.

Corona seen through a faint dark glass before totality.

M. C. Bulard. LAMBESSA,
18th July, 1860.

"Comptes Rendus," liii., p. 511.

Cette auréole commença à se former au bord de la lune un peu avant l'obscurité totale, du côté opposé à l'endroit où les dernières portions du croissant solaire disparaissaient—en présentant l'apparence de grains de chapelet signalés par BAILY.

The corona began to form while Baily's beads were still visible on the opposite side of the moon.

Mr. Pogson. MASULIPATAM,
18th Aug., 1868.

Report of the Government Astronomer.

(p. 7.) I saw no trace of the corona, either with the naked eye or with the telescope, after the first flash of returning sunlight.

Mr. Hudson. SAN ANTONIO,
22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

I saw the corona about three-quarters of a minute longer than the totality.

Mr. J. Norman Lockyer. BÉKUL,
12th Dec., 1871.

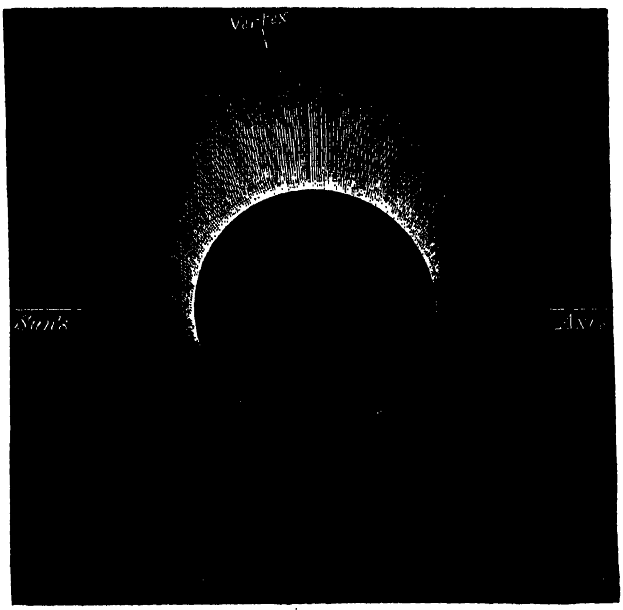
"Nature," Vol. v., p. 219.

[While observing the structure of the corona with a 6-inch refractor,] the eclipse terminated for the others but not for me. For nearly three minutes did the coronal structure impress itself on my retina, until at last it faded away in the rapidly increasing sunlight.

Mr. A. R. Dawson. KAITS,
12th Dec., 1871.

MS. Reports of the 1871 Expedition.

Just before the totality, rays suddenly sprang up along the arc of the black moon on the side opposite to the disappearing crescent. They were longest in the centre and were about equal in length to one half the diameter of the moon. . . . . . . I have depicted their appearance in the sketch.



CHAPTER XV.

STARS SEEN BEFORE TOTALITY.

ONLY bright stars such as Venus, Jupiter, Mercury, and Sirius, are, it would appear, visible before totality. Venus, which, it should be remembered, has frequently been observed in full daylight, was perceived in the eclipse of 1715, when the sun was three-fourths eclipsed; Jupiter has been detected five minutes before totality, but MARTIN SAAR, who observed it, knew pretty accurately the part of the heavens in which to look for it.

M. Massini, PARIS, 3rd May, 1715,

"Mémoires de l'Académie" for 1715, p. 109.

On apperçût Venus à la vûe simple, lorsque le Soleil fut éclipsé de neuf doigts. On distingua aussi dans le plus fort de l'éclipse Mercure, qui étoit entre le Soleil et Venus, et qui fut remarqué long-temps par S.A.R. Monseigneur le Duc d'ORLÉANS.

Venus seen when sun was nine digits covered. Mercury also seen before totality.

Herr Schidlowsky. LIPEZK, 7th July, 1842.

"Astr. Nachr.," Vol. xx., p. 231.

Schon 10 Minuten vor dem Eintritt derselben [the totality] wurde Venus deutlich gesehen, auch Sirius zeigte sich, während noch etwas von der Sonne sichtbar war.

Venus clearly seen 10 m. before totality, and Sirius while part of the sun was still visible.

Sir G. B. Airy, HILL NEAR GÖTTENBURG, 28th July, 1851.

"Memoirs of the R.A.S.," Vol. xxi., Pt. i., p. 5.

About a quarter of an hour before the totality Venus shone out with much brilliancy.

Martin Saar. VITORIA, 18th July, 1860.

"Über Totale Sonnenfinsternisse," Dr. von Mädler, Jena, 1861.

Jupiter 5 m. before totality, Venus soon after.

(p. 13.) Jupiter 5 Minuten vor Eintritt der Totalität, Venus bald darauf.

Herr G. Schulz. VITORIA, 18th July, 1860.

"Über Totale Sonnenfinsternisse," Dr. von Mädler, Jena, 1861.

Venus visible 15 m. before totality.

(p. 15.) Venus war schon 15 m. vor Anfang der Totalität mit blossem Auge sichtbar, Jupiter später.

CHAPTER XVI.

PROMINENCES SEEN BEFORE AND AFTER TOTALITY.

THE time during which prominences have been seen before and after the total phase varies from a few seconds to about six minutes.

1851.	**Dawes.**	About 5 seconds after totality.
	Hind.	4 seconds after totality.
1862.	**Struve.**	Nearly 3 minutes after the first ray had broken out.
	De la Rue.	Several minutes (probably five) before totality.
	Bruhns.	6·3 minutes after totality.
1869.	**Hough.**	Nearly a minute before totality.
	Murray. **Swift.**	Nearly a minute previous to totality, and remained visible almost 6 minutes after totality.
1871.	**Dawson.**	No time mentioned.

The Rev. W. R. Dawes. ROEVELSBERG, NEAR ENGELHOLM, 28th July, 1851.

"Memoirs of the R.A.S.," Vol. xxi., Pt. i., p. 91.

To my great astonishment [one of the prominences] *continued visible for about five seconds*, as nearly as I could judge, *after the sun began to re-appear*, which took place many degrees to the south of the situation it occupied on the moon's circumference. It then faded away, but *it did not vanish instantaneously*.

Mr. Hind. ROEVELSBERG, NEAR ENGELHOLM, 28th July, 1851.

"Memoirs of the R.A.S.," Vol. xxi., Pt. i., p. 83.

The largest and most remarkable of the prominences was situated about 5° north of the parallel of declination, on the western limb of the moon. . . . . . . I saw this extraordinary prominence *four seconds after the*

end of totality, but at this time it appeared detached from the sun's limb, the strong white light of the corona intervening between the limb and the base of the prominence.

M. O. Struve. POBES, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

After the reappearance of the sun I returned to the prominences, one of which I could distinctly see until nearly three minutes after the first ray of the sun had broken out; at that time the nearest cusp of the sun's crescent was at a distance of 10° to 20° of the moon's circumference from its place.

Mr. De la Rue. RIVABELLOSA, SPAIN, 18th July, 1860.

Bakerian Lecture on the Eclipse of 1860, "Phil. Trans.," Pt. i., 1862, p. 25.

Several minutes (probably five) before totality, I entirely removed the dark glass, and found that the sun's image might be looked at without the slightest inconvenience after reflection by a plain glass. . . . . I perceived a luminous prominence, about 20° to the west of the zenith, shining with great brilliancy.

Professor C. Bruhns. TARAZONA, 18th July, 1860.

"Berichte der Kön. Sächs. Gesellschaft der Wissenschaften," Math. Phys. Classe, Sitzung am 12 Dec., 1860, p. 227.

Protuberances seen for 6·3 m. after totality.

Bis zu 3 Uhr 58 Minuten, also 6·3 Minuten nach dem Ende der Totalität, gelang es mir die Protuberanz zu sehen.

Professor G. W. Hough. MATTOON, ILLINOIS, 7th Aug., 1869.

"Journal of the Franklin Institute," Jan., 1870, pp. 61, 62.

As the crescent of solar light grew less and less, every eye was intently watching for any unusual appearance. Nearly a minute before

totality, we saw with wonder a red flame suddenly shoot out from the upper edge of the moon, and shortly after, the remarkable and beautiful phenomenon of Baily's Beads.

Professor David Murray. MATTOON, ILLINOIS,
Mr. Lewis Swift. 7th Aug., 1869.

"The Total Eclipse of Aug. 7th, 1869," by Prof. G. W. Hough, 8vo, Albany, 1870.

(p. 17.) The most remarkable of the red flames was seen nearly a minute previous to totality, and remained visible almost six minutes after totality had ended. . . . . Its disappearance was peculiar, and entirely contrary to our expectations. It was presumed that a luminous flame, when brought in opposition to a stronger light, would gradually grow less and less, until it finally faded away. No such phenomenon was manifested during its disappearance. It seemed to retain its intensity, until it was entirely cut off, or apparently lifted up by the advancing crescent of solar light. This phenomenon was also remarked by Mr. SWIFT.

Mr. A. R. Dawson. KAITS,
12th Dec., 1871.

MS. Reports of the 1871 Expedition.

I saw a protuberance before the sun had entirely disappeared.

CHAPTER XVII.

BAILY'S BEADS.

The length of time during which Baily's Beads have been noticed as being visible before the beginning and after the end of totality has been variously estimated. One would have expected that the time of their duration would have chiefly depended upon the height of the mountains which happened to be upon the moon's limb at the time of the eclipse; and that for stations situated near the central line of totality, the estimates of the time of their duration would not greatly differ. But such does not appear to be the case. Thus,—

1851.	**Dunkin.**	At Christiania.	15 seconds before totality.
	Dawes.	At Rœvelsberg.	3 or 4 seconds before.
	Feldt.	At Frauenburg.	about 40 seconds before.
1860.	**Janson.**	At Burgos.	10 seconds before.
	Bianchi.	At Vitoria.	4 to 5 seconds before.
1869.	**Hough.** **Swift.**	At Mattoon.	$5\frac{1}{2}$ seconds before. The time marked on a chronograph.
	Langley.	At Oakland (near the S. limit of totality).	15 seconds or more.
	Dean.	At Shelbyville.	3 seconds before.

Gilliss in 1858 describes the crescent as breaking up some twelve or fifteen seconds before totality, and Baily in 1836 speaks of the phenomena as lasting for only "six or eight seconds, or perhaps ten at the utmost."

In describing the eclipse of 1851 Dawes says that he was particularly struck with the fact that the lunar mountains broke through the crescent at a time when it appeared to be considerably broader than the height of the mountains which had previously been seen projecting beyond the general outline of the moon's circumference. The same fact is noted by Lysaght, who says that the successive formation of the dark lines connecting the limbs of the sun and moon gave "the idea of posts raised *gradually* from

behind hillocks" on the moon's limb. The increase in the breadth of the solar crescent by irradiation is also referred to by Baily in his original account of the annular eclipse of 1836, where he says that when the dark lines connecting the two limbs *suddenly* gave way the moon appeared to be perceptibly advanced on the face of the sun. (The order of events is naturally reversed during an annular eclipse.) But to proceed with the phenomena as observed at the commencement of a total eclipse. The dark lines across the solar crescent are seen to grow shorter and broader, and the intervening bright spaces assume rounded forms which have been compared by—

1836.	Baily.	To a luminous string of beads.
1842.	Baily.	String of beads.
1851.	Dunkin.	Small particles or beads of light.
	Swan.	Bright spaces at first rudely rectangular, afterwards rounded.
1860.	Wray.	Irregularly shaped fragments which at no time resembled beads.
	Janson.	Not like beads, but resembling the appearance of water as it dries up under a hot sun.
1869.	Seaver.	Diamond-shaped beads which appeared to adhere to each other and to the limbs of the sun and moon.
	Langley.	Long and thin fragments.
	Dean.	String of brilliants which disappeared like snow under a white heat.

Many of the observers describe the beads or intervening dark spaces as merging or flowing into one another like drops of water. See also the observations given in the next chapter, where the motion of the beads during their dissolution is treated of.

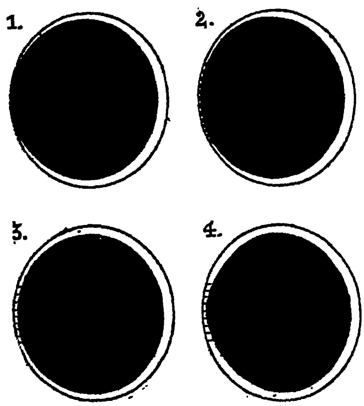
Baily at his second observation in 1842 failed to see the black lines, although he caught sight of the beads. Olufsen and Littrow in 1851 both failed to see the black lines, and Struve at the same eclipse saw neither black lines nor beads, although he carefully looked for them, and Feldt only saw a slight indication of two parallel grey lines across the crescent.

Mr. Francis Baily. Inch Bonney, near Jedburgh,
15th May, 1836.

"Memoirs of the Royal Astronomical Society," Vol. x., pp. 1—40.

(p. 5.) When the cusps of the sun were about 40° asunder, a row

of lucid points, like a string of bright beads, irregular in size and distance from each other, *suddenly* formed round that part of the circumference of the moon that was about to enter, or which might be considered as having just entered, on the sun's disc. Its formation indeed was so rapid that it presented the appearance of having been caused by the ignition of a fine train of gunpowder. This I intended to note as the correct time of the formation of the annulus, expecting every moment to see the thread of light completed round the moon, and attributing this serrated appearance of the moon's limb (as others had done before me) to the lunar mountains, although the remaining portion of the moon's circumference was comparatively smooth and circular as seen through the telescope (see fig. 1). My surprise, however, was great on finding that these luminous points, as well as the dark intervening spaces, increased in magnitude, some of the contiguous ones appearing to run into each other like drops of water; for the rapidity of the change was so great, and the singularity of the appearance so fascinating and attractive, that the mind was for the moment distracted, and lost in the contemplation of the scene, so as to be unable to attend to every minute occurrence.



Finally, as the moon pursued her course, these dark intervening spaces (which, at their origin, had the appearance of lunar mountains in high relief, and which still continued to the sun's border) were stretched out into long, black, thick, parallel lines, joining the limbs of the sun and moon; when all at once they *suddenly* gave way, and left the circumferences of the sun and moon in those points, as in the rest, comparatively smooth and circular; and the moon perceptibly advanced on the face of the sun.

* * * * * *

The appearances here recorded passed off in less time than it has now taken me to describe them; but they were so extraordinary and so rapid, that all idea of time was lost, except by the recollection afterwards of what had passed, for I was so riveted to the scene that I could not take my eye away from the telescope to note down anything during the *progress* of this

phenomenon. I estimate, however, that the whole took up about six or eight seconds, or perhaps ten at the utmost.

I have endeavoured to delineate the several phases above mentioned in three of its most striking stages. Fig. 1 represents the first appearance of the luminous string of beads just formed round the edge of the moon, which was almost instantaneous. Fig. 2 represents a *continuation* of the same phenomenon, or the moon farther advanced on the face of the sun; but still apparently adhering to its border by means of the dark, thick, irregular spaces which separate the luminous portions, now become somewhat enlarged in size. Fig. 3 represents still a *continuation* of the same phenomenon; the dark parts being now stretched out into long black lines, which seemed to connect together the limbs of the sun and moon, and are here represented as they appeared immediately before their sudden rupture and total disappearance.

In all these representations the moon is supposed to be proceeding in a horizontal direction, from the left hand towards the right. I cannot describe these phenomena (or rather this phenomenon, for it was one *continuous* appearance) more correctly than by supposing, for the moment, that the edge of the moon was formed of some dark glutinous substance, which by its tenacity adhered to certain points of the sun's limb, and by the motion of the moon was thus drawn out into long threads, which suddenly broke and wholly disappeared. After the formation of the annulus thus described, the moon preserved its usual circular outline during its progress across the sun's disc, till its opposite limb again approached the border of the sun, and the annulus was about to be dissolved, when all at once (the limb of the moon being at some distance from the edge of the sun) a number of long, black, thick, parallel lines, exactly similar in appearance to the former ones above mentioned, *suddenly darted forward* from the moon and joined the two limbs as before, and the same phenomena were thus repeated, but in an inverse order. For, as these dark lines got shorter, the intervening bright parts assumed a more circular and irregular shape, and at length terminated in a fine curved line of bright beads (as at the commencement), till they ultimately vanished, and the annulus consequently became wholly dissolved. The time employed in this act of dissolution (if I may so express myself) was about the same as that at its formation; but the rapid and progressive change in the appearances, and

their striking character, so riveted my attention again, that I am unable to speak more decidedly on the time occupied than on the first occasion. The same reason also prevents me from stating the precise number of the dark lines. I should think, however, that they were not fewer than six or more than ten. The impression on my mind, from recalling all the circumstances to my recollection, is that there were about eight. They were as plain, as distinct, and as well defined, as the open fingers of the human hand held up to the light.

Mr. Francis Baily. PAVIA, 8th July, 1842.

"Monthly Notices," Vol. v., p. 210.

I at first looked out very narrowly for the *black lines* which were seen in the annular eclipse of 1836; as they would probably precede the *string of beads*. These lines, however, did not make their appearance; or, at least, they were not seen by me. But the *beads* were distinctly visible.

Major Lysaght. HINGOLEE, 9th Nov., 1847.

"Monthly Notices," Vol. viii., p. 131.

Immediately before the formation of the annulus, and on the western edge, a dark line was seen to connect the limbs of the sun and moon, and gave the idea of a post raised *gradually* from behind one of the hillocks, and extending to the sun's limb. This was followed by another; both remained a few seconds, but the manner of their disappearance was not particularly observed; then appeared a thin thread of light, which was noted as the formation of the annulus.

* * * * * *

The moon's limb again became smooth, leaving a hillock on the eastern side, which, as she advanced, *gradually* elongated, and became pointed, when another post was erected like the former two, but more slowly (so much so that I was nearly turning my eye in another direction, not expecting to see the phenomenon), and remained somewhat longer; this broke in the centre, and the two parts shrunk slowly into the limbs of the sun and moon.

Mr. Dunkin. CHRISTIANIA,
28th July, 1851.

"Memoir of the R. A. S.," Vol. xxi., Pt. i., p. 12.

About 15 s. before the beginning of total darkness, the narrow line of the sun broke up into numerous small particles or beads of light. . . . .

The time noted for the beginning of total darkness was when I lost sight of the last spot of light.

Mr. W. Swan. A HILL NEAR GÖTTENBURG,
28th July, 1851.

"Transactions of the Royal Society of Edinburgh," Vol. xx., Pt. iii., p. 340. *See also* "Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 73.

The limb of the moon now became quickly joined to that of the sun by numerous thick lines, which immediately began to run into each other with great rapidity, like contiguous drops of water, so that the eye could not follow their motion. They occupied nearly all the remaining crescent of the sun, and were so numerous that I had not time to count them before their fluctuating movements rendered it impossible to do so. The spaces between the lines were at first rudely rectangular, but gradually became rounded so as to resemble a string of bright beads, and then finally disappeared.

The Rev. W. R. Dawes. RŒVELSBERG, NEAR ENGELHOLM,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 88.

About three or four seconds before the totality, the fine crescent was broken up into several pieces or "beads," eight or ten in number; but they did not all appear at the same instant: they were not round, and were very unequal in length; *the dark intervals between the bright portions corresponding exactly with the positions of the mountains on the moon's edge, and evidently caused by them.* These intervals were largest towards the southern extremity of the crescent. I was particularly struck with the fact, that the lunar mountains broke through the crescent while it yet appeared to be

considerably broader than the extent of their own projection beyond the general outline of the moon's circumference. This was very observable in the case of the largest of them, which divided the crescent so long before it seemed capable of doing so, as to take me quite by surprise. The lunar mountains had thus the appearance of being *drawn out into narrow black threads*, reaching to the exterior edge of the sun.

Professor Olufsen. CALMAR, 28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 219.

Black ligaments across crescent not seen.

Die schwarzen Striche, die man bei früheren Gelegenheiten zwischen den Rändern der Sonne und des Mondes beobachtet hat, habe ich nicht gesehen.

Dr. C. L. von Littrow. RIXTHÖFT, 28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 132.

Baily's black lines not seen.

Von F. BAILY's schwarzen Linien sah ich nichts.

Dr. L. Feldt. FRAUENBURG, 28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 162.

Two grey bands across the crescent.

Ich bemerkte etwa 40 Secunden vor dem Verschwinden des letzten Lichtstrahls . . . . eine leise Andeutung von zwei fast parallelen grauen Streifen, welche wahrscheinlich von dem rauhen Mondrande herrührten.

M. Otto Struve. LOMZA, 16th July, 1851.

"Beobachtung der Totalen Sonnenfinsterniss," von Otto Struve, p. 7.

Not the least trace of Baily's beads or streaks seen at the beginning of totality.

Beim Eintritt der totalen Verfinsterung, bei welchem ich auch nicht die geringste Spur von den Bailyschen Perlen oder Streifen wahrgenommen habe.

Lieut. Gilliss.

NEAR OLMOS, PERU,
7th Sept., 1858.

"An Account of the Total Eclipse of the Sun on Sept. 7th, 1858, as observed near Olmos, Peru."—"Smithsonian Contributions to Knowledge."

(p. 8.) At from twelve to fifteen seconds before the beginning of totality the entire line—then perhaps 35° in extent—broke up into masses of unequal length, showing detached portions wholly separated from the rest by dark lines.

Mr. Wm. Wray.

CAMMESA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

As the sun disappeared the whole of the slender crescent was broken up into fragments exactly corresponding to the lunar depressions, but, as it appeared to me, in a curiously exaggerated manner. Whilst the moon's mountains approached very near to the solar limb, their summits seemed suddenly to shoot out and meet the limb, forming dark bridges, which bore a resemblance to parallel lines in the thin crescent. The broken-up portions then underwent many changes of form, and disappeared at successive intervals, at no time resembling beads, but as irregularly shaped fragments which before vanishing passed into points still of great brilliancy but without sensible diameter.

Mr. T. C. Janson.

BURGOS,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

The lower part of the limb broke into three irregular fragments—not like beads, but resembling the appearance of water as it dries up sometimes under a hot sun. These remained in sight for about ten seconds.

M. Bianchi.

VITORIA,
18th July, 1860.

"Über Totale Sonnenfinsternisse," Dr. von Mädler, Jena, 1861.

(p. 20.) Vier bis fünf Sekunden erblickte ich in meinem 50 Mal vergrössernden terrestrischen Fernrohr die schwarzen Streifen sich auf der

Black stripes seen to form across the thin crescent just before totality.

schmalen Sichel abzeichnen. Sie erschienen stärker und gedrängter im untern Theile der Sichel. Es schien mir (versichern kann ich es nicht) dass auch am obern Ende die Streifen dichter waren; in der Mitte waren sie entschieden am sparsamsten. . . . . . Die Streifen schwanden und flossen in einander; die Totalität brach ein.

Mr. E. P. Seaver. SPRINGFIELD, ILLINOIS, 7th Aug., 1869.

"United States Coast Survey Report for 1869," Appendix, No. 8, p. 43.

As the crescent grew very thin, beads began to form at each end, little black lines with sharp ends apparently shooting from the moon's disc in a radial direction across the thin crescent and chopping it into beads. At last the crescent was reduced to a string of beads about an inch and a half long,* which trembled for an instant and then suddenly disappeared. . . . . The beads were not globular, but diamond-shaped, from an apparent adhesion to each other and to the limbs of the sun and moon.

Prof. G. W. Hough. MATTOON, ILLINOIS, 7th Aug., 1869.

"Journal of the Franklin Institute," Jan., 1870, p. 62.

The duration of Baily's Beads was accurately recorded on the chronograph by Mr. SWIFT and myself, and found to be $5\frac{1}{2}$ seconds.

Prof. S. P. Langley. OAKLAND, KENTUCKY, 7th Aug., 1869.

"United States Coast Survey Report for 1869," Appendix, No. 8, p. 22.

"Baily's Beads," so called, were seen for fifteen seconds or more. They were long and thin, rather than points of light, and apparently moved with the moon. [The station was near the southern limit of the path of totality. The sun was only seen to be totally eclipsed for about one second.]

* The phenomenon was observed on the screen of a camera attached to a telescope. The sun's disc was $4\frac{3}{4}$ inches in diameter.

Mr. Geo. W. Dean. SHELBYVILLE, KENTUCKY,
7th Aug., 1869.

"United States Coast Survey Report for 1869," Appendix, No. 8, p. 26.

About three seconds before this [the commencement of totality] was recorded, the delicate line of sunlight suddenly separated into minute fragments, resembling very much a string of brilliants, which disappeared like snow under a white heat, producing one of the most brilliant and startling effects of the total eclipse. I have no doubt of the fact that the dark lines which I saw for three seconds before totality were identical with the elevations which I saw upon the moon at the instant of first contact.

CHAPTER XVIII.

SWIMMING ROUND AND FLOWING TOGETHER OF BAILY'S BEADS.

Of the observers who describe Baily's Beads as appearing to move, there are some who speak of the whole line of luminous points as swimming, waving, or moving together as a whole; while others describe the phenomenon as if only the separate beads of light changed form or flowed into one another.

Of the first class, Grover describes the luminous points as appearing to wave from the extremities to the centre of the crescent like gas lights in the wind. Ashe speaks of fragments which appeared to swim from the centre towards the cusps. Rottenberg describes flashes of light running along the moon's limb at the instant of contact, but does not mention the direction of their motion; and Langley, whose observation is given in the last chapter, says that the points of light, as seen from his station near the southern limit of totality, seemed to move with the moon.

Stephenson and Hough, as well as Baily, Swan, and Bianchi, whose observations are given in the last chapter, describe some of them the beads, and some the dark intervals, as running or flowing into one another like drops of water or globules of mercury.

Seaver, in 1869 (see last chapter), says that the beads trembled for an instant before they disappeared.

On the other hand, Dunkin in 1851, and Tennant in 1871, are very definite in their assertion that there was no running or flowing together of the beads during their disappearance.

Captain John Grover. NEAR NICE,
8th July, 1842.

"Monthly Notices," Vol. v., p. 207.

Just before the total obscuration, when about three minutes of the sun's disc remained visible, a most splendid sight presented itself; this crescent of light was suddenly changed to luminous points, which appeared to wave from the extremities to the centre of the crescent; presenting precisely the appearance I have witnessed at an illumination when a *device in gas* has been swept over by a strong breeze.

Mr. Robert Stephenson. FREDRICHSVAARN,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 43.

The reappearance of the sun was remarkably instantaneous, representing not a fine thread of light, as it had done on disappearing, but a series of spots of silver light, which gave the idea of globules of mercury rushing amongst each other along the edge of the moon. In two or three seconds their apparent motion ceased, and they settled into a steady crescent.

Mr. Dunkin. CHRISTIANIA,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 12.

The beads, if I may call them so, were perfectly steady, their only change being their gradual disappearance as the total obscuration of the sun approached.

Lieut. E. D. Ashe. AULEZAVIK ISLAND,
18th July, 1860.

"Report of the Superintendent of the United States Coast Survey," Appendix No. 21, pp. 24, 25.

The bright crescent was reduced to a thin line of light. Shortly afterwards it broke up into fragments, which appeared to swim from the centre towards the cusps.

The Baron de Rottenberg. VALENCIA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

I did not see Baily's Beads as they are usually described, but as flashes of light running along the moon's limb at the instant of contact. What I saw, and what I am quite certain about, is this: Before the sun entirely disappeared, there remained at the right extremity three or four points of light—some separated from each other—exactly resembling the points of light seen on the moon's limb when two or three days old, running into the darkness of the terminator.

Prof. G. W. Hough. MATTOON, ILLINOIS,
7th Aug., 1869.

"The Total Eclipse of Aug. 7th, 1869," by Prof. G. W. Hough. 8vo, Albany, 1870.

The slender crescent of light was suddenly broken up into numerous globules, resembling drops of water flowing together, or a string of beads. One observer compared it to a chain of sausages of unequal lengths.

Lieut.-Col. Tennant. DODABETTA, NEAR OOTACAMUND,
12th Dec., 1871.

Report of Col. Tennant, p. 5.

In following the retreating cusp, I saw what must have been Baily's Beads; but they were clearly small specks of light passing hollows in the moon's limb, and enlarged by the irradiation of the telescope. I kept one of them some few seconds in the place corresponding to the middle of the slit, and am quite satisfied that there was no running or flowing.

CHAPTER XIX.

THE MOON AND CORONAL RAYS SEEN TO ROTATE.

THE appearance of rotation described in the following extracts is not confined to the first few seconds of totality, though WYBERD and BROGI describe the phenomenon as if it was especially visible just after the moon's disc had appeared to rush forward on covering the sun. The other observers speak of the corona as if it continued to revolve. LETHBRIDGE says "during totality," and ULLOA is careful to say that he did not observe the revolving corona till five or six seconds after the immersion. See also the observation of HAASE given in the chapter on the apparent motion of coronal rays during totality. HAASE's observation was made only a few seconds before the end of totality.

Dr. Wyberd. CARIGFERGUS, IRELAND,
29th March, 1652.

" Astronomia Britannica," by Vincent Wing, London, 1669, p. 356.

Luna momento quasi et eximprovisò, totam se intra Disci Solis orbitam seu ambitum (quatenus conspectui nostro appareret) tam agiliter injiciebat, ut *circumagere aut circumvolvere videretur*, sicut Çatillus seu *Lapis Molaris superior* (Cursor dictus). Sole tunc circumcirca ejus limbum seu marginem splendidulo vel corusco apparente, ut esset quasi *Spectaculum Rotationis* dictum, aspectu sanè valde jucundum ac notatu dignum, et quidem æqualitèr undique post unum temporis minutum (tamquam conjectare poteram), circiter dimidium digiti, aut $\frac{1}{3}$ saltem (quantùm etiam conjicere licebat) instar circuli luciduli, vel Coronæ subrutilæ; et tunc pro certo centralitèr conjuncta erant Luminaria quoad apparentiam.

The moon suddenly threw itself within the solar disc with such agility that it seemed to go round like an upper mill-stone. The sun then appeared around the limb, affording a pleasant and remarkable spectacle of rotation.

Don Ulloa. OBSERVED AT SEA, 24th June, 1778.

"Phil. Trans.," Pt. i. for 1779.

(p. 108.) Five or six seconds after the immersion we began to observe round the moon a very brilliant circle of light, which seemed to have a rapid circular motion, something similar to that of a rocket turning about its centre.

M. Arago. MONTPELLIER, 8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 333.

Many persons at Montpellier asserted that the corona turned round like a firework.

A Montpellier, plusieurs personnes prétendirent que la couronne n'était pas fixe, qu'elle tournait sur son centre, comme les soleils des feux d'artifice.

Capt. Lethbridge, R.N. H.M.S. *Trafalgar*, GIBRALTAR, SPAIN, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

During the totality a bright ray of light appeared to radiate from the centre around the circumference of the moon, varying in length.

Giuseppe Brogi. MARIA LOUISA OBSERVATORY, 22nd Dec., 1870.

"Monthly Notices," Vol. xxxi., p. 58.

At the moment of totality the sun and moon seemed to run together like one wheel running inside another in opposite directions; then immediately the corona appeared.

Officer on board H.M.S. Caledonia. ARCE REALE, NEAR CATANIA, 22nd Dec., 1870.

Report of Lecture at the Royal Institution by Mr. Lockyer, "Nature," Vol. iv., p. 233.

[Mr. Lockyer said] When I saw an officer of one of the ships at Catania, I asked him if he had taken a drawing of the corona. "No," he said. I asked him, "Did you see any rays?" "Yes." "Then why did you not make any drawing of them?" His answer was, "How on earth could you draw a thing that was going round like a firework?"

CHAPTER XX.

THE MOON APPEARS TO JUMP FORWARD AT THE BEGINNING AND END OF TOTALITY.

BESIDES the observations of MACLAURIN, BAYNES, ROSARIO, and BOESINGER, see those of WYBERD and BROGI given in the last chapter. WYBERD and BAYNES describe the even motion of the moon as appearing to be accelerated at the moment when the lunar limb blotted out the last trace of the photosphere.* MACLAURIN speaks of the motion of the moon as appearing to be quicker at the formation and dissolution of the annulus; and BOESINGER describes the moon as appearing to make a jerk eight or ten seconds before the end of totality—that is, at the moment when it would be uncovering the brighter layers of the chromosphere. ROSARIO, though he speaks of the sun as appearing to jerk, no doubt refers to the same phenomenon.

* Observers have repeatedly noticed that the solar crescent appears up to the last moment before its extinction as a band of sensible width, and the sudden disappearance of such a comparatively broad line of light will no doubt account for the apparent acceleration alluded to. The increase in the breadth of the solar crescent due to irradiation is well illustrated by an observation of Piazzi Smyth, who observed the Annular Eclipse of March 15th, 1858, at Brentwood, in Essex. In describing it in the "Monthly Notices," vol. xviii., p. 185, he says:—"All the middle part of the eclipse was seen by the naked eye, through driving clouds, nimbi and cirrostrati the whole of the time. The effect of a dense part of a cloud in decreasing irradiation and of a rare part in increasing it, was very remarkable, the solar crescent being made alternately thin and thick." See also the observation of Dawes in the chapter on Baily's Beads, where he remarked that the lunar mountains appeared to break through the solar crescent, while it appeared considerably broader than the extent of their own projection beyond the general outline of the moon's circumference.

Prof. Colin Maclaurin. CROXBY, NEAR AYR, SCOTLAND, 18th Feb., 1736.

Hutton's Abridgment of the "Phil. Trans.," Vol. viii., p. 170.

It was observed that the motion of the moon appeared more quick in the formation and dissolution of the annulus than during its continuance. This is particularly described by Mr. FULLARTON, of Fullarton, in a very exact account of the eclipse as it appeared at his seat at Croxby, near Ayr, on the west coast of Scotland. He writes that "the annulus appeared to be nearly of a uniform breadth during the greater part of the time of its continuance, but séemed to go off very suddenly; so that when the disc of the moon approached to the concave line of the sun's disc, they seemed to run together like two contiguous drops of water on a table, when they touch one another;" and he adds, that it came on in the same way. This appearance seems to be accountable from the same optical deception as the former.

Mr. R. E. Baynes. SAN LUCAR, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition

I saw Baily's Beads with perfect distinctness. . . . . Then the moon seemed to throw herself over the sun, and immediately all at once the corona shot out.

Mr. P. C. Rosario. MANGALORE, 11th Dec., 1870.

MS. Reports of the 1871 Expedition.

The sun did not reappear gradually or evenly, but seemed to make two or three jerks at first.

M. J. Boesinger. OOTACAMUND, 12th Dec., 1871.

"Nature," Vol. v., p. 300.

About eight or ten seconds before totality ended, the moon appeared as if it had made a jerk (stumbled against something).

CHAPTER XXI.

THE CHROMOSPHERE SEEN AS A CONTINUOUS RED ARC.

TOWARDS the end of totality the prominences upon the sun's western limb appear to increase rapidly in number, and at length they are seen to be joined together at their base by a streak of red light which has in some cases been traced extending over an arc of more than 60° along the moon's limb. STANNYAN speaks of the blood-red streak seen by him as continuing to be visible not longer than six or seven seconds of time. HALLEY says two or three seconds, and BULLOCK two seconds.

A similar red arc is also visible at the commencement of totality. LITTROW describes that seen by him just after the sun's disappearance as 0'·2 broad.

The early date of some of the following observations* seems to indicate that the red arc must (at all events in some eclipses) be conspicuously visible. It is intensely bright compared with the corona; indeed, BULLOCK seems to have mistaken it for the reappearing sun. The colour of the arc is variously described, thus :—

* Later observations are very numerous, but since the continuous character of the chromosphere is now clearly proved by the spectroscope, we have not thought them worth extracting. Prof. Grant has collected several observations made during annular and total eclipses, and has embodied them in a paper entitled, *On Telescopic Observations of the Phenomena seen in continuity with the Moon's Limb during Eclipses of the Sun, and the results which have been therefrom deduced*, published in the "Monthly Notices," vol. xxxii., pp. 33—41. It is, however, due to Prof. Grant to mention that long before the date of this paper he had recognized the fact that the prominences were united at their base by a continuous red arc. In a chapter of his "Physical Astronomy," written in 1850, he speaks of what we now call the chromosphere as a "stratum of nebulous matter," and distinctly describes it as enveloping the photosphere. Bullock's observation, made in 1868, is given to show the intense brightness of the red arc. For observations of the chromosphere as seen in 1860, see inter alia the Reports of Airy, Aguilar, Byrne, Perry, Rottenberg, and Weyer.

1706.	**Stannyan.**	6 or 7 seconds before the end of totality.	A blood-red streak.
1715.	**Halley**	2 or 3 seconds before the end of totality.	Narrow streak of dusky but strong red light.
	Louville.	Towards the end of totality.	A circle of very vivid red.
1806.	**De Ferrer.**	Towards the end of totality.	A zone, similar in appearance to a cloud illuminated by the rays of the sun.
1842.	**Schumacher.**	Shortly before the end of totality.	A narrow rose-red layer.
1850.	**Kutczycki.**	An instant before the reappearance of the sun.	Like a narrow girdle of flames.
1851.*	**Littrow.**	Just after the commencement of totality.	A carmine-red edge to the moon's limb, with a saw-like outline.
1860.	**Grant.**	Before the end of totality.	Streak of red light extending over an arc of about 25° of the moon's limb.
1868.	**Bullock.**	About 2 seconds before the end of totality.	A thin rim of beaded fire, like intensely glowing coals.

Captain Stannyan. BERNE, 12th May, 1706.

"Phil. Trans." for 1706, p. 2240.

The sun . . . . at its getting out of the eclipse was preceded by a blood-red streak of light, from its left limb; which continued not longer than six or seven seconds of time. Then part of the sun's disc appeared all of a sudden.

Dr. Edmund Halley. ROYAL SOCIETY'S HOUSE, CRANE COURT, LONDON, 3rd May, 1715.

"Phil. Trans." for 1715, p. 249.

And about two or three seconds before it [*i.e.* the emersion], on the same western side where the sun was just coming out, a long and very narrow streak of a dusky but strong red light seemed to colour the dark edge of the moon, though nothing like it had been seen immediately after

* See also the observation of Schmidt given in the next chapter. He describes two arcs of the chromosphere as being visible 4 seconds before the end of totality.

the immersion. But this instantly vanished upon the first appearance of the sun.

M. de Louville. LONDON, 3rd May, 1715.

"Mémoires de l'Académie" for 1715, p. 123.

J'ai observé que vers la fin de l'éclipse entière il y avoit autour du bord de la Lune, qui n'avoit pas encore quitté le Soleil, un cercle d'un rouge très-vif dont le limbe de la Lune étoit bordé.

A band of vivid red observed around the limb of the moon towards the end of the total eclipse.

Mr. de Ferrer. ALBANY, 16th June, 1806.

"Transactions of the American Philosophical Society," 1st Series, Vol. vi., p. 274.

A little before the illumination of the lunar disc, I observed a zone to issue concentric with the sun, similar to the appearance of a cloud illuminated by the rays of the sun.

Prof. Schumacher. VIENNA, 7th July, 1842.

"Annalen der Sternwarte in Wien," Vol. ii., Neuer Folge, p. xxxiii.

Kurz vor dem Ende der totalen Finsterniss erhob sich an dem Theile des Mondrandes, wo der erste Lichtfunke austreten sollte, eine schmale rosenrothe Schichte, die aber, als dieser Lichtfunke erschien, zugleich mit den rothen Bergen, und dem Lichtringe, der den Mond umgab, verschwand.

Shortly before the end of totality, a narrow rose-red layer seen along that part of the moon's limb where the sun's light first appeared.

M. Kutczycki. HONOLULU, 8th Aug., 1850.

"Comptes Rendus," Vol. xxxii., p. 581.

Un instant avant l'apparition du Soleil, ... il a apparu sur le bord de la Lune, se projetant sur la portion très-lumineuse de la couronne, une multitude de petits points très-rapprochés, ... le tout faisait l'effet d'une très-mince ceinture de flammes occupant au moins 60 degrés, dont les sommets roses formaient un cercle rouge vif sur le bord de la Lune avant l'émersion.

An instant before the reappearance of the sun there appeared along the moon's limb a multitude of little points very near together, which gave the effect of a very narrow band of flame, at least 60° long.

Dr. C. L. von Littrow. RIXTHÖFT,
28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 132.

A carmine-red band, with a saw-like outline, around the moon's limb, near where the sun had disappeared, about 0'·2 broad.

Was mir nun nach abgenommenem Blendglass zunächst auffiel, war eine karminrothe, sägeförmig begrenzte Einfassung des Mondrandes, die nahe an der Stelle wo die Sonne verschwunden war . . . . am breitesten etwa 0'·2 breit erschien.

Prof. Grant. SIERRA DE TOLOÑO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

While I was engaged in observing the last-mentioned prominence I perceived a little below it several other small peaks which had just come into view; and a few seconds afterwards the motion of the moon disclosed a long stratum uniting them together at their bases, giving to the whole phenomenon the aspect of a sierra resting on the moon's limb and extending over an area of about 20°. This continuous succession of prominences was intensely red, resembling in colour the most beautiful vermilion. Its light was very much condensed, there being an entire absence of streaks which characterized the larger prominences. The reappearance of the sun was preceded by an excessively narrow band of red light apparently touching the moon's limb, and connecting itself with the sierra previously observed. This long streak of light extended over an arc of about 25° of the moon's limb.

Capt. Bullock. MANTAWALU KIKI, CELEBES,
18th Aug., 1868.

MS. Observations of the 1868 Eclipse.

(p. 11.) About two seconds before, and at the position where the sun reappeared, there suddenly broke out a thin rim of beaded fire, like intensely glowing coals, which I first took to be the sun's limb, and was hesitating whether or not I should call "time," when the sun itself burst out in its splendour.

CHAPTER XXII.

TELESCOPIC OBSERVATIONS OF YOUNG'S STRATUM.

SCHMIDT, FEARNLEY,* SECCHI, and TACCHINI have observed that the lower layers of the chromosphere which are uncovered by the moon's limb, in the few seconds immediately preceding the end of totality appear of a decidedly whiter hue than the prominences and upper parts of the chromosphere which have been previously uncovered. SCHMIDT describes the red arc of the upper chromosphere as appearing to be separated from the dark limb of the moon by an intensely shining, silvery-white line of light —which has, no doubt, frequently been mistaken for the returning light of the photosphere; and hence, probably, the double observations of the commencement and end of totality described in the next chapter.

Besides the telescopic observations of the lower or white chromosphere, see the spectroscopic observations of YOUNG, PYE, and BURTON, in 1870, MACLEAR and FYERS in 1871, and STONE in 1874, from which we learn that the number of bright lines visible in the lower chromosphere is almost innumerable.

Mr. Hind. ROEVELSBERG,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 83.

[Speaking of a prominence on the western limb, Mr. Hind says:] I saw this extraordinary prominence *four seconds after the end of totality*, † but

* Prof. Fearnley, in the MS. Reports of the Himalaya Expedition, gives two coloured drawings, which show an arc of some 30° of red chromosphere, separated from the moon's limb by a paler layer.

† Mr. Hind appears to have mistaken Young's stratum for the reappearing photosphere. This assumption derives additional support from the fact that he observed the corona "*on the western side* [that is on the side of the reappearing crescent] at least five seconds after the reappearance of the sun."

at this time it appeared detached from the sun's limb, the strong white light of the corona intervening between the limb and the base of the prominence. . . . . . On the south limb of the moon appeared a long range of rose-coloured flames. . . . . . The bright rose-red of the tops of these projections gradually faded towards their bases, and along the moon's limb appeared a bright narrow line of deep violet tint.

Dr. Julius Schmidt. RASTENBURG, 28th July, 1851.

"Beobachtung der totalen Sonnenfinsterniss:" Schmidt, Bonn, 1852.

A few seconds before the end of totality the chromosphere was seen as a [illegible] red [illegible] along the moon's limb; [illegible] and before the reappearance of the sun the red arc was seen to be [illegible] from the moon's limb by a line of silver-white light.

(p. 8.) Etwa höchstens 4 Secunden vor dem bezeichneten Momente sah ich plötzlich lebhaft rothes Licht in Gestalt zweier sehr zarten Linien sich auf dem Rande des Mondes fortbewegen. . . . . Es war als flösse rothglühendes Metall über den schwarzen Mondrand hin, und doch war diese scheinbar fliessende Bewegung wiederum nur die Folge vom Fortrücken des Mondes, der das Licht dieser rothen Schicht in der Nähe beider Protuberanzen zuerst hervortreten liess, weil sie dort augenscheinlich als die Fortsetzung der Böschungen der oftgedachten Gestalten erschien und höher lag. $1^{s}.5$ vor dem Ende der Totalität vereinigten sich beide Linien in der Mitte zu einem vollständigen höchst zarten Bogen von stark rosenrothem Lichte, der vielleicht einem kleineren Krümmungsradius als dem des Mondes, angehörte. In seiner ganzen Erstreckung schien er aus einer sehr grossen Menge der kleinsten Protuberanzen zu bestehen, von denen einige den Bogen etwas überragten. Nun glaubte ich im Momente der Bildung dieses Bogens das Sonnenlicht erwarten zu müssen. In demselben Augenblicke trennt sich die rothe Curve vom dunklen Mondrande, und zwischen beiden tritt eine silberweisse strahlende und höchst intensive Lichtlinie hervor, concentrisch mit der rothen, scharf von dieser, noch mehr vom Monde geschieden. Eine Secunde lang mochte ich sie gesehen haben,

zweifelnd, wegen der doch zu geringen Helligkeit, ob das Ende der Totalität eingetreten sei, als plötzlich, sichelförmig im gewaltigen Glanze das wahre

Licht der Sonne wie ein Blitzstrahl hervorschoss, und in demselben Augenblicke die ganze Reihe der wunderbaren Erscheinungen zum Verschwinden brachte.

Padre Secchi. DESIERTO DE LAS PALMAS, 18th July, 1860.

"Relazione delle Osservazioni, etc.": P. Secchi, Rome, 1860.

(p. 18.) Intanto l' arco coronato di protuberanze si faceva sempre più vivo e più largo, e la lor base rivestiva una tinta più chiara che sfumava in un bianco deciso. La sua estensione totale era almeno di 60°.

An arc, crowned with protuberances was seen for at east 60° along the moon's limb; its base appeared of a decided white colour.

Sig. A. Tacchini. TERRANOVA, 22nd Dec., 1870.

"Rapporti della Commissione Italiana," p. 131.

Vidi che l' arco roseo si trasformava in un bianco pallido alla base, presagendo la fine del fenomeno.

The red arc transformed itself into a pale white at its base

CHAPTER XXIII.

DOUBLE OBSERVATION OF THE COMMENCEMENT AND END OF TOTALITY.

It will be seen from the extracts given in this chapter that the brightness of the solar envelopes immediately surrounding the photosphere is such that observers have frequently been puzzled in determining the exact moment of the commencement or end of totality. According to the observations of Airy, Robinson, Smyth, (Tisserand, Olry, Hatt, Stephan,) and Rosario there would appear to be a bright layer above the photosphere with a defined upper limit. But according to the observations of Secchi and Weyer, both made in 1860, the degradation in brightness from the photosphere outwards is perfectly gradual. It is possible (and from spectroscopic observations it appears probable) that the bright layer at the base of the chromosphere may differ materially in thickness at different eclipses. It will be noticed that in 1851 the interval between the two signals for totality of Robinson was 5 s. In 1868 the interval between the two sets of observations at Wha-Tonne was 12 s.

Sir G. B. Airy. Church of the Superga, near Turin, 8th July, 1842.

"Monthly Notices," Vol. v., p. 217.

I have now to mention a very strange observation. I was viewing the sun most carefully with the dark glass upon the eyepiece, while the small illuminated ring was closing rapidly; my watch was lying on the parapet on which the short telescope-stand was placed, and I was counting its beats, with the intention of observing the time which might elapse between the appearance of Mr. Baily's beads and the total obscurity. I saw the moon's limb advance to the sun's, and cover it completely.

I withdrew my eye for a moment from the eye-piece, when I heard my companion remark that the sun was nearly gone. I said firmly, "It is out." On being assured that it was not, I again applied my eye to the telescope, and to my infinite surprise I again saw the narrow ring of the sun's disc, not quite so bright as before. I again saw the moon's limb advance to the sun's limb, and cover it. In other words I saw the totality completed twice. With regard to the *fact*, I can only say that I was at the time most fully alive to everything that occurred, and that I was specially prepared for an observation which I expected to be one of the most important in the whole eclipse; and I have not the smallest doubt that the thing occurred, under the circumstances in which it was viewed with my telescope, precisely as I have stated. . . . .

I was assured by my companion that there was a cloud upon the sun at the time when I first saw its extinction, and this cloud, though not sufficient to conceal the edge of the sun's disc from the naked eye, might be sufficient to conceal it as viewed in a telescope, in which the specific brightness of any surface is much less than to the naked eye, and which also was armed with a dark glass.

Dr. Robinson. ISLAND OF BUE,
Professor Piazzi Smyth. 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 26.

Dr. ROBINSON [who had noted the commencement of totality at 2 h. 55 m. 13 s. also] gave a second signal which was not heard by the person at the chronometer, but which he thinks was 5 s. after the other. During the time when Dr. ROBINSON's signals were being given Professsor P. SMYTH continued to see the sun's limb of a very visible breadth and well defined, but faint through clouds. But he observed at Dr. ROBINSON's signals sudden depressions in the brightness of the surface, and at last, when he also gave the signal for the beginning of totality, the limb seemed to vanish at once, while having still a sensible breadth and being well defined.*

* Prof. Piazzi Smyth remarks that these variations may have been the effect of the passing clouds, but he is rather inclined to think that, from their instantaneity, they must have been produced by variations of the solar light itself, and that the fact of such variations would pro-

Prof. Weyer. VITORIA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The duration, which I found 2 h. 43 s., was immediately after compared by some of the observers. As far as I recollect, Mr. SCHULZ found it 2 m. 48 s., and Mr. MÄDLER 2 m. 50 s., Mr. D'ARREST 2 m. 53 s., and Mr. THIELE, I believe, nearly the same. The differences proved to be in the observed end of totality, and may perhaps be explained by the layer of red light, where the sun was to reappear, growing more and more vivid as the end approached.

Padre Secchi. DESIERTO DE LAS PALMAS, 18th July, 1860.

"Relazione delle Osservazioni, etc.", P. Secchi, Rome, 1860, p. 14.

The occultation was not instantaneous like that of a star, but gradual. Having taken away the dark glass he was surprised still to see a thread of white sunlight, which was so bright that the eye could hardly bear it.

L' occultazione però non fu istantanea come quella delle stelle, ma molto graduata, sicchè stimo impossibile accertarne la frazione del secondo con precisione e la credo assai dipendente dall' oscurità del vetro colorato.

Tolsi allora immediatamente l' offuscante dall' oculare e fui sorpreso a rivedere tuttavia un filo di Sole bianco, e di luce si forte che mi offese l' occhio, ma il suo splendore andò si prestamente diminuendo che potei sostenerlo.

M. Tisserand.
M. Olry.
M. Hatt.
M. Stephan.

WHA-TONNE, 18th Aug., 1868.

" Rapport sur l'Observation de l'Eclipse de Soleil," par M. Stephan, p. 19.

Tisserand and Olry noted the time of the commencement of totality as 12 s. earlier than tha noted by Hatt and Stephan.

Le premier contact intérieur fut observé par MM. TISSERAND, OLRY, HATT, et STEPHAN, qui trouvèrent les nombres suivants exprimés en temps moyen de Wha-Tonne.

bably be much more evident when the sun was almost obscured by a thick cloud than when totally uncovered, as the eye is so very much more sensible to a difference in the brightness of two objects when they are both faint than when they are both bright.

Professor P. Smyth observed the commencement of totality at 2 h. 57 m. 9 s., or 1 m. 56 s. after Dr. Robinson's first signal.

Tisserand.	23 h. 39 m. 23·1s.
Olry.	23 h. 39 m. 23·8s.
Hatt.	23 h. 39 m. 35·1s.
Stephan.	23 h. 39 m. 35·9s.

Ces quatre nombres présentent une remarquable particularité : les deux premiers sont presque identiques ; il en est de même des deux derniers ; mais la moyenne de ceux-ci et celle de ceux-là diffèrent de 12·1 s. . . . . Lorsque le contact se produit, la disparition de la lumière n'est pas instantanée ; pendant plusieurs secondes, il subsiste, de part et d'autre, du point du tangence, un arc brillant très-mince et d'un éclat tellement vif qu'il peut produire une illusion sur la réalité du contact . . . . Je n'hésite pas à considérer le globe du soleil proprement dit comme environné d'une couche diaphane mince et très-brillante, surmontant immédiatement ce que l'on est convenu d'appeler la photosphère.

Or, M. Tisserand est sûr d'avoir noté l'instant du contact proprement dit. M. Olry n'a pu voir que ce contact ; M. Hatt a continué de compter la seconde jusqu'à la cessation de toute lumière vive, et, quant à moi, distinguant parfaitement le contour extérieur de la couche, j'ai marqué l'instant de son occultation par le bord de la lune.

Mr. P. C. Rosario. Mangalore, 11th Dec., 1871.

MS. Reports of the 1871 Expedition.

The sun did not reappear gradually or evenly, but seemed to make two or three jerks at first.

CHAPTER XXIV.

APPROACH OF THE MOON'S SHADOW SEEN AT TOTALITY.

THE rate at which the shadow of the moon travels over the earth's surface is so great that few observers except those situated upon high ground overlooking a great extent of country have been successful in observing it in its passage over the earth; but as seen in the air, or travelling over distant clouds, its motion can, it would seem, be easily followed.

FORBES, AIRY, J. BECK and W. BECK, Miss AIRY, GRANT, and RANYARD describe the shadow of totality seen in the distance as appearing like a dark storm upon the horizon.

AIRY, PLATT, Mrs. FARRELL, ARCHIBALD, HILL, and SAMUELSON describe the shadow as visible in the air. Mrs. FARRELL speaks of the coming darkness as appearing to rise from the horizon, "like the lifting of a dark curtain." HILL speaks of the approaching shadow as "sweeping upwards and eastwards," and SAMUELSON as gliding "swiftly up over the heavens." PLATT describes the appearance of the shadow in the air as like a dark column or very dark cloud, and FORBES speaks of the approach of the "colonne ténébreuse." NONES describes the shadow as of a "dark rose colour," and HILL refers to "the deep violet shadow."

Lady AIRY and WINNECKE speak of the shadow as appearing like smoke, MENTESINO describes it as a "wall of fog," SAMUELSON as a "vaporous shadow," and PEROWNE says that it was neither like shadow nor vapour. The same appearance is no doubt referred to by AIRY in 1851, who speaks of a "duskiness in the south-east" which he immediately perceived to be the eclipse shadow.

FORBES was so confounded by the frightful velocity with which the shadow swept over the earth towards him, that he felt as if the great building on which he was standing was commencing to fall over in the

direction of the coming darkness. BIDDULPH describes the rapidity of the motion of the shadow as "perfectly frightful;" he involuntarily listened for the rushing noise of a mighty wind. PLATT talks of the "frightful rapidity" with which the darkness advanced, and EASTMAN speaks of "the rush of a peculiar, almost tangible darkness." On the other hand HILL says that the motion of the shadow was "much slower and more majestic" than he had been led to expect.

SILVERSTOLPE, GRANT, MYER, LINDSAY, RANYARD, and LANE, or those with them, failed to observe the passage of the shadow, although their attention was specially directed to looking for it.

KRAG, RAGOONATHA CHARY, HILL, and MYER all noticed that the darkness did not commence instantaneously with what appeared to them to be the time of the passing of the shadow, but that the darkness gradually increased until in a few seconds it appeared to be at its height. This may possibly be accounted for by the illumination which would be derived from the clouds and sky in the neighbourhood not yet immersed in the moon's shadow, and does not necessarily indicate that the light of the solar crescent was only gradually extinguished.

M. Duillier. GENEVA,
12th May, 1706.

"Phil. Trans." for 1706, p. 22.

A little before the total obscuration, the country on the west side did already seem overcast with darkness, and after the total obscuration the darkness was seen to leave us more and more and to fly eastward.

Dr. William Stukeley. BOSTON, LINCOLNSHIRE,
2nd May, 1715.

"Itinerarium Curiosum," 2nd edition, Vol. i., p. 182.

I saw both sides of the shadow come from a great distance, and pass beyond us to a great distance.

Prof. Forbes. OBSERVATORY OF TURIN, 8th July, 1842.

"Sur l'Eclipse Totale de Soleil du 8 Juillet, 1842."—"Bibliothèque Universelle de Genève," Dec., 1843.

The sun was covered by clouds, but the totality shadow was observed upon the horizon like a distant storm. Then it was seen to approach like a column of darkness, sweeping through the air with a frightful velocity, that made the building on which he was standing appear to lean towards the coming shadow.

(p. 8.) Quelques instants avant l'obscurissement totale je dirigeai mes regards autour de l'horizon, qui était en général assez bien éclairé; les vapeurs dans le lointain réfléchissaient beaucoup de lumière, étant encore éclairées per la majeure partie du disque solaire, à cause de leur distance de la ligne de l'éclipse centrale. Aussi les Alpes, autant que nous avons pu les voir, paraissaient-elles beaucoup plus claires que les pays dans notre voisinage. J'aperçus seulement dans la direction sud-ouest une ombre noire, semblable à celle que projette un orage près d'éclater, qui obscurcit les Alpes au midi du Mont-Viso. Ce n'était pas autre chose que l'ombre lunaire arrivant à nous du midi de la France, où l'éclipse était également totale. J'en fus d'abord convaincu, parce que cette ombre ténébreuse vola vers nous avec une rapidité vraiment effrayante. M. CARLINI a pris la peine de calculer la vitesse de sa marche sur la surface de la terre, qui fut ici (si ma mémoire ne me trompe pas) d'*un mille et demi* (d'Italie) *par seconde*, ou de plus de trois mille lieues par heure. D'après ce que je viens de dire, la tache d'ombre fut, pour ainsi dire, un objet visible, et dont l'œil pouvait mesurer la distance. Ceux qui ont vu approcher une machine locomotive, avec une vitesse seulement de 10 à 15 lieues par heure, peuvent se former une idée de la stupéfaction que causait l'approche de cette colonne ténébreuse, avec une vitesse que l'on peut comparer à celle d'un éclair, et qui, en moins d'une demi-minute, lui fit traverser toute la plaine comprise entre les Alpes maritimes et la ville de Turin. J'avoue que ç'a été pour moi le spectacle le plus effrayant que j'ai jamais vu; comme il arrive toujours dans le cas de mouvements brusques, inattendus et silencieux, le spectateur semble confondu des mouvements relatifs et des mouvements réels. Je me sentis un instant presque étourdi, comme si le vaste bâtiment qui était sous mes pieds s'inclinait vers le côté d'où arrivait l'éclipse, ou plutôt comme si la nature entière chancelait par l'action d'une puissance extérieure qui semblait tout près de nous, bien que cachée sous les ténèbres d'une nuit presque instantanée.

Je ne puis douter que la circonstance de l'invisibilité du soleil caché

par les nuages, n'ajouta beaucoup à l'effet mystérieux et terrible de l'ombre volante.

Prof. Liveing. FREDERIKSVÆRN, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 105.

When the totality approached, the passage of the shadow was not so rapid but that I could see the clouds to the north-west grow dark before the last direct beam of the sun was extinguished. And at the reappearance of the sun it was still more remarkable; the clouds to the north-west lightened up, making it much brighter where I stood; and I had time to exclaim that the sun was going to appear, and to turn my eyes towards him, an appreciable interval before he actually showed himself.

Capt. Biddulph. DRÖBAK, 18 MILES S.W. OF CHRISTIANIA, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 37.

I can best describe that the coming of the shadow could be appreciated by the sensation of darkness coming over one as a thick dark atmosphere spreading itself over sky and land to the north-west, and more distinctly on the clouds and sky overhead. At last the light cloud I saw distinctly put out like a candle. . . . . .

The rapidity of the motion of the shadow and its intenseness produced a feeling that something material was sweeping over the earth at a speed perfectly frightful. I involuntarily listened for the rushing noise of a mighty wind.

Lieutenant Krag. RINGERIGET, NOT FAR FROM CHRISTIANIA, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 31.

I had a very extensive view, and could clearly notice the shadow on the approach of total darkness, travelling across the country, and gradually increase until the darkness was at its height; and I am perfectly certain it did not come on instantaneously.

Sir G. B. Airy. HILL NEAR GÖTTENBURG,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 8.

My eye was caught by a duskiness in the south-east, and I immediately perceived that it was the eclipse shadow in the air, travelling away in the direction of the shadow's path. For at least six seconds this shadow remained in sight, far more conspicuous to the eye than I had anticipated. I was once caught in a very violent hail-and-thunder storm on the table-land of the county of Sutherland, called "The Moin," and I at length saw the storm travel away over the North Sea; and this view of the receding eclipse-shadow, though by no means so dark, reminded me strongly of the receding storm. In ten or twelve seconds all appearance of the shadow had passed away.

Colonel Silverstolpe. CHRISTIANSTADT,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 96.

In the moment before the eclipse being total, it could not be observed that the shadow of the moon was running fast over the country from the west to the east, only that the daylight quickly diminished.

Mr. Platt. AULEZAVIK ISLAND,
Mr. H. B. Nones. 18th July, 1860.

Prof. Stephen Alexander's Report, "Coast Survey Report," 1860, Appendix 21, p. 18.

Acting Sailing-Master PLATT, whose attention had been particularly directed to these [the approach and departure of the shadow] in the programme of phenomena to be looked for, saw the darkness advance from the west with a frightful rapidity, and then pass over. It appeared like a dark column or a very dark cloud.

Mr. NONES speaks of the latter part of the shadow as being of a "dark rose colour which could be traced in the valley below."

The approach of the light following the shadow was very distinctly to be marked.

sufficiently bright to form a background on which the moon's limb can be distinguished, yet that as the moon in its passage across the sun passes over prominences, and even brighter parts of the corona, it may be rendered visible, and may again be lost. It should be noticed, however, that none of the observers, except HARDY, who mention that they have seen the limb outside the sun's disc, describe the precautions they took to avoid being biassed by the presence in the field of the contiguous portion of the moon's limb projected upon the photosphere.

Mr. Willughby.
Dr. Pope.
Mr. Hook. LONDON,
Mr. Philips. 22nd June, 1866.

"Philosophical Transactions," Hutton and Shaw's abridgment, Vol. i., p. 111.

The greatest obscurity of the eclipse was somewhat more than seven digits. About the middle, beween the perpendicular and westward horizontal radius of the sun, viewing it through Mr. Boyle's 60-foot telescope, there was perceived a little of the limb of the moon without the disc of the sun; which seemed to some of the observers to come from some shining atmosphere* about the body either of the sun or moon.

Mr. G. Dollond. (No place given.)
29th Nov., 1826.

"Monthly Notices of the Royal Astronomical Society," Vol. i., pp. 26-7.

The morning was cloudy, but soon after the commencement of the eclipse there was a partial opening in the clouds, through which Mr. Dollond saw *a considerable part of the limb of the moon which had not yet entered on the disc of the sun.* Continuing his observations, after a short

* See also the account of the observations of Dembowski in 1851, and Weiss in 1867. The same shining atmosphere is evidently alluded to by Dembowski as "una porzione di fascia di un colore per lo meno più chiaro del disco lunare;" and by Weiss as "einem schwachen gelben Lichschein" around the sun's limb.

Lady Airy. HILL ABOVE HEREÑA,
18th July, 1860.

"Monthly Notices of the R. A. S.," Vol. xxi., pp. 14, 15.

The moment of totality had come; the whole air was at once filled with darkness, yet it was darkness through which the mountain and valley could be distinctly seen. To me it seemed as if we were in the midst of a streaky shower of smoke or fine dust, which, however, was perfectly clear, and which could not be felt. It was only for a moment that I was struck with this appearance sweeping along the valley between us and the northern hills.

Miss H. Airy. HILL ABOVE HEREÑA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

When the shadow disappeared in the south-east among the clouds the sky there had a pitch-black appearance.

Dr. Winnecke. HILL OF SANTA MARINA, 3 MILES FROM POBES,
18th July 1860.

MS. Reports of the Himalaya Expedition.

I heard a great noise and shouting of the crowd, and instinctively turned my eyes, and saw the moon's shadow approaching like a smoke. With that moment the last ray of the sun disappeared.

Senor Mantesino. BANDERAS, BILBAO,
18th July, 1860.

MS. Observations of the Himalaya Expedition.

I did not see the approach or receding of the shade at the critical moment; my attention being then drawn to other objects; but those who saw it say it appeared as a wall of fog travelling at a rapid rate over the landscape.

Mr. J. G. Perry. HILL OF CANTABRIA, NEAR LOGROÑO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

When the critical moment was at hand, the darkness sweeping over a landscape twenty or thirty miles in extent and advancing right at me was in the highest degree sublime and imposing.

Prof. Grant. SIERRA DE TOLOÑO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

In the region of the heavens whence the shadow was travelling the sky appeared black as pitch . . . . . . As the totality approached I endeavoured to detect the progress of the shadow over the earth's surface,* but without success.

The Rev. J. J. S. Perowne. ALI, NEAR VITORIA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

Three or four minutes before the total obscuration we saw the great shadow come sweeping down the mountains and over the plains. I know not whether to call it shadow; it seemed to fill the air as well as to pass over the ground. It is commonly spoken of as "the shadow," but the word is inadequate. It is neither shadow nor vapour, nor can any word describe it. . . . . . .

[After totality.] The great broad shadow which had come from the N.W. swept away again towards the S.E., and a sudden golden light seemed to creep under the darkness.

C. Ragoonatha Chary. VUNPURTHY,
18th Aug., 1868.

"Report of the Government Astronomer upon the Observations of the 1868 Eclipse," p. 24.

I had previously instructed the by-standers to watch carefully if they

* The station selected by Prof. Grant was on the southern slope of the Sierra de Toloño. He describes it as commanding a most extensive view of the valley of the Ebro, along which the moon's shadow was to pass.

could see the sweeping of the shadow from the west, and they unanimously cried out, just at the beginning of totality, "Darkness coming, and covering hill after hill; the shadow has come over us." At that moment it did not become very dark, but only a few seconds after it became so much more so, that I was unable to see some steps near me distinctly.

Mr. George Davidson. KOHKLUX, NEAR KOT-KÁGH-TOO, 7th Aug., 1869.

"United States Coast Survey Report for 1869," Appendix No. 8, p. 67.

When I found that the clouds had hidden the moon from me, I looked up the valley of the Chilkaht, which makes a small angle with the path of totality, and saw, on the north-east flank of the mountain range on the right bank, the line of the coming light sweeping down rapidly, showing through rifts in the clouds, and beautifully lighting up the snow-filled gulches and crests of the mountains . . . . . . Governor WILLIAM H. SEWARD and party were on the river . . . . . . they had an excellent view of the approaching and retreating shadow as it swept down the valley.

Mrs. Farrell. ST. PAUL JUNCTION, PLYMOUTH COUNTY, IOWA, 7th Aug., 1869.

"Washington Observations, 1870," Appendix ii., p. 176.

Perfect silence reigned during the remaining moments of sunlight . . During this stillness Mrs. Farrell distinctly saw the moon's shadow rapidly approaching in the air. It appeared to go upwards from the western horizon like the lifting of a dark curtain.

Prof. Eastman. DES MOINES, IOWA, 7th Aug., 1869.

"Washington Observations," 1870, Appendix ii., p. 104.

The total obscuration was coincident with the appearance of the corona and protuberances, and with the rush of a peculiar, almost tangible, darkness.

Mr. G. D. Archibald. HANOVER COLLEGE, INDIANA,
7th Aug., 1869.

"United States Coast Survey Report for 1869," Appendix No. 8, p. 50.

The sweep of the shadow was distinctly observed; it was first noticed on the river-hills, some two miles below the college, travelling rapidly towards Madison; when totality arrived, the hills at the back of Madison, about four miles above, were yet in sunlight; in a few seconds they, too, were in darkness. When the shadow returned the Madison hills were again lighted, while the observers were still in the gloom. In a few seconds it swept swiftly by, and down the river for fourteen miles, when it was lost to view on the land, but was visible for several seconds after in the air, sweeping to the south-east.

President Hill. MATTOON, ILLINOIS,
27th Aug., 1869.

"Journal of the Franklin Institute," Jan., 1870, p. 67.

The approach of the deep violet shadow in the air from the W.N.W., a little to the right of the sun, and its receding in the opposite quarter, was much slower and more majestic and beautiful than we had been led to expect. The gradual diminution of light during the eclipse had revealed the presence of faint cirro-stratus clouds in the horizon of what appeared, both before and after the eclipse, a cloudless sky. The transition from penumbra to umbra, although rapid, did not seem absolutely instantaneous. It was a sweeping upward and eastward of a dense violet shadow.

Mr. Arthur Searle. NEAR SHELBYVILLE,
7th Aug., 1869.

"United States Coast Survey Report for 1869," Appendix No. 8, p. 19.

The shadow of the moon was noticed, I understand, by some observers towards the north, but does not seem to have been regarded as a striking phenomenon (the driver of the stage between Eminence and Shelbyville says that it appeared to him no more distinct or dark than an ordinary cloud shadow).

Dr. Crosier. NEW ALBANY, INDIANA,
7th Aug., 1869.

"Account of Observations made at New Albany by E. S. Crosier," p. 4.

As if by magic a bright halo shot out upon every side of the darkened disc of the moon. . . . . At the same instant a bright fan-light expansion of light swept across the northern sky.

General Albert J. Myer. WHITE TOP MOUNTAIN, NEAR ABINGDON, VIRGINIA,
7th Aug., 1869.

"Washington Observations, 1870," Appendix ii., p. 195.

The approach of the moon's shadow did not appear to be marked by any defined line, or the movement of any dark column of shade through the air. The darkness fell gradually, shrouding the mountain ranges and the dim world below in most impressive gloom. Our guides had been instructed to watch for the shadow as described and to call to us at the glasses. They saw nothing of which to give notice.

Lord Lindsay. MARIA LOUISA OBSERVATORY,
22nd Dec., 1870.

"Monthly Notices," xxxi., p. 52.

I had requested all my party to notice particularly if the shadow of the moon was to be seen advancing through the air, but none of them saw it.

Captain Noble. ORAN,
22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

The sky was covered with clouds at Oran during the totality of the eclipse . . . . Of the direct phenomena I saw nothing. But I did see the western horizon turn to an awful purple, and the shadow as it travelled through the air communicated something of the same tint to the previously blackish grey clouds over head.

Mr. Ranyard. VILLASMUNDA,
22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

We were situated on the summit of a small hill from which we commanded a distant horizon in all directions.

As the crescent began to disappear we all directed our attention to the part of the horizon from which the shadow of totality was about to approach us. Two minutes before the last gleam of sunlight disappeared there was a dark appearance as of a coming storm, but although the two sappers kept their attention fixed on that part of the horizon until after totality had commenced they failed to see the shadow approaching us through the air as has been described at former eclipses. Mr. SAMUELSON, however, caught sight of it.

Mr. H. Samuelson. VILLASMUNDA, 22nd Dec., 1870.

"Nature," Vol. iii., p. 311.

Immediately before totality commenced, a dark vaporous shadow glided very swiftly up over the heavens from the westward, or a little south of west, and as it came on towards us, seemed to swallow up the earth, leaving it dark in its rear, until at the moment of totality it reached the sun.

Mr. J. Homer Lane. CATANIA, 22nd Dec., 1870.

"United States Coast Survey Report for 1870," Appendix 16, p. 10.

I watched for the rising of the dark curtain, an appearance mentioned as having been seen by some on the approach of the shadow in the eclipse of 1869. The phenomenon in question was not, however, perceived on this occasion, and subsequent reflection suggested that the smaller diameter of the shadow gave less reason to expect it.

Mr. Seabroke. CATANIA, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

It gradually got darker, and I saw the moon's shadow rapidly approaching on the clouds above.

General Abbot. MOUNT ETNA, 22nd Dec., 1870.

"United States Coast Survey Report for 1870," Appendix No. 16, p. 14.

At an elevation of 7,500 feet I was overtaken by the shadow, which swept with great rapidity over us, darkening the gloom to an awe-inspiring degree.

CHAPTER XXV.

THE HEAVENS APPEAR TO DESCEND AT TOTALITY.

THE entirely altered illumination of the heavens during totality causes the clouds above the observer which are no longer projected upon a bright background to appear much nearer than before. If he is looking towards the zenith as totality comes on the observer sees the clouds* above him appear to drop towards the earth, as described by STUKELY in the last century, and by AIRY in 1842. The gloom about the observer also alters his estimate of distances. If his station be upon a mountain the plain below him, according to the observation of MATHEWS and REYNOLDS, appears to become more distant.

Although the alteration of apparent distance takes place most rapidly at the moment of totality, it would appear from the observation of BURR, made in England in 1860, that the increasing nearness of clouds may be perceived long before the eclipse is total

1724.	**Stukely.**	Darkness as it were dropped upon us.
1842.	**Airy.**	Cloud over head seemed to be descending rapidly.
1858.	**Paroissien.**	Sky seemed very near upon the earth.
1860.	**Heath.**	Clouds seemed to come down on to the mountains.
	Lowe.	Clouds became lower as eclipse advanced.
	Buckingham.	Clouds seemed very near and low and horizon contracted.
	Mathews.	The plain of Orduña appeared to sink to twice its ordinary depth.
	Reynolds.	Orduña seemed lost in a gulf of immeasurable depth.
	Perry.	Clouds seemed to descend.
	Burr.	(Eclipse not total,) clouds appeared to be descending rapidly.
1869.	**Pell.**	Totality came like a pall dropped suddenly over everything.
1870.	**Noble.**	The vault of the heavens seemed to contract.

* The same effect has been observed with regard to the apparent distance of the heavens though clear from cloud. See the observation of Weeden in the Chapter on the "Colour of the Sky during Totality," p. 165.

Dr. William Stukely. HARADON HILL, NEAR AMESBURY, 11th May, 1724.

"Itinerarium Curiosum," Second Edition, Vol. i., p. 180.

Now I perceived us involved in total darkness and palpable, as I may aptly call it; though it came quick, yet I was so intent that I could perceive its steps, and feel it as it were drop upon us, and fall on the right shoulder (we looking westward) like a great dark mantle, or coverlet of a bed, thrown over us, or like the drawing of a curtain on that side.

Sir G. B. Airy. CHURCH OF THE SUPERGA, NEAR TURIN, 8th July, 1842.

"Monthly Notices," Vol. v., p. 217.

The gloom increased every moment; the candle seemed to blaze with unnatural brilliancy; a large cloud over our heads, whose appearance I had not particularly remarked, but which I think was of cumulo-stratus character, became converted into a black nimbus, blacker if possible than pitch, and seemed to be descending rapidly; its aspect became horribly menacing, and I could almost imagine that it appeared animated. Of all the appearances of the eclipse, there is none which has dwelt more powerfully upon my imagination than the sight of that terrible cloud.

Rev. Challis Paroissien. HARDINGHAM, NORFOLK, 15th March, 1858.

"Monthly Notices," Vol. xviii., p. 249.

At the time of the greatest obscuration,* it was sufficiently clear to observe the dull leaden appearance of the violet sky in the zenith and in the north. It seemed very near upon the earth.

Mr. R. F. Heath. PEÑA DE CASTILLA, SANTANDER, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The brilliant effect of the colours on the horizon was heightened by the dark indigo of the clouds above, and by the blue darkness in which the whole landscape was enshrouded. The clouds seemed to come down on to the mountains.

* The eclipse was annular.

Mr. E. J. Lowe. FUENTE DEL MAR,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

The clouds became lower as the eclipse progressed, and after totality increased in height.

Mr. J. Buckingham. CAMMESA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

[During totality] all the clouds, except near the moon, seemed very near and low and the horizon contracted.

Mr. H. M. Mathews. HILL ABOVE ORDUÑA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

The effect of the shadow of totality upon the landscape was most extraordinary. The plain of Orduña beneath appeared to sink to twice its ordinary depth.

Mr. Robert Reynolds. HILL ABOVE ORDUÑA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

Orduña seemed lost in a gulf of immeasurable depth, and darkness far far away below.

Mr. J. G. Perry. HILL OF CANTABRIA, NEAR LOGROÑO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

As the total obscuration advanced, the clouds, which had been very high and of a bright reflecting character, became black, and seemed to descend nearer to the earth.

Mr. Burr. HIGHBURY, NEAR LONDON,
18th July, 1860.

"Monthly Notices of the R. A. S.," Vol. xxi., p. 25.

During the greatest obscuration dense clouds covered the heavens . . . . They were very dark, and seemed lower than usual; in fact, they gave the impression of a rapid descent on the earth.

Mr. Pell. NEW ALBANY, INDIANA,
7th Aug., 1869.

"Account of Observations made at Albany," by E. S. Crosier, p. 8.

Total obscuration came instantaneously, and had much the effect of a pall dropped suddenly over everything.

Captain Noble. ORAN,
22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

The sky was covered with clouds at Oran during the totality of the eclipse . . . . I noticed that at the time of greatest obscuration the clouds appeared to descend, or, to put it in another way, the vault of the heavens seemed to contract.

CHAPTER XXVI.

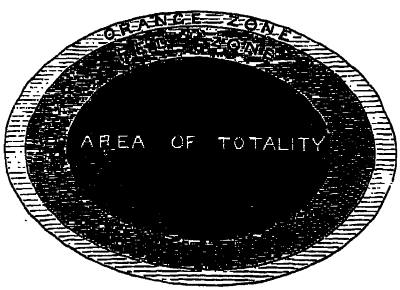
COLOURS ON CLOUDS.

To an observer standing within the area of totality the heavens above appear dark, while the horizon is brilliantly illuminated with tints of red and orange.

Two theories have been put forward as to the origin of these colours, the one that they are produced in the same manner as the ordinary tints of sunset, and the other that the red clouds are illuminated by the light of the hydrogen chromosphere, while the orange clouds are lit up by the lower incandescent strata that give out the brilliant D line, or even by the mixed spectrum of YOUNG's reversing layer.

According to the first of these theories, the tinted clouds would derive their illumination from the area outside the cone of totality illuminated by the rays from the thin solar crescent. The light which passed through the lowest layers of the atmosphere would lose most of the short wave lengths, and we should have, as in an ordinary sunset, red on the lower clouds and yellow above.

According to the direct illumination theory, the tinted clouds would all be situated just outside the area of *total* darkness. The orange clouds would lie in a zone on the outside and the red clouds would occupy a decidedly broader zone within them, thus.



In the red zone the heavens and the clouds, whatever their altitude, would all be tinted red, and in the orange zone all would be orange. On this theory the orange clouds would first make their appearance on the approach of totality, and then the red, and after totality first would come the red and then the orange.

On looking over the following observations one is at once struck with

the fact that the tinted clouds are by no means confined to a narrow zone around the area of totality. BURR and DAWES in 1860 saw tinted clouds from their stations in England, though many hundred miles away from the shadow path. BUCKINGHAM * and BECK observed coloured clouds which from their descriptions appear to have been within the area of total darkness; and HENRY, HOBBES, LOWE, WINNECKE, GRANT, PEROWNE, GRIFFITH, SAMUELSON, and RANYARD observed colours either before totality commenced, or after it was well over, thus:—

1860.	Henry.	Just before the total obscuration, copper-coloured clouds in the region of the sun.
	Hobbes.	As totality approached, yellow glare in E. and N.E.
	Lowe.	Before totality commenced, orange and red like sunrise in E.
	Winnecke.	About 15 m. before totality, dusky yellowish colour on horizon to N.W.
	Grant.	When the sun was reduced to a very slender crescent, the horizon in the direction opposite to the region of totality a dull orange hue.
	Perowne.	Just before totality, horizon in S.W. of the brightest orange colour conceivable.
1870.	Griffith.	Before the commencement of totality, rose-coloured cloud 5° or 6° W. of sun.
	Samuelson.	For some seconds after totality, deep red copper-coloured clouds to the S.E.
	Ranyard.	For 40 or 50 seconds after totality, red clouds on the horizon to the S.E.

RÜMKER looking from within the area of totality describes the colour on the horizon as yellow above, red beneath. NAFTEL in his picture gives orange above, red beneath. BUCKINGHAM describes the horizon as "bronzy yellow and lurid just above," and adds "like some sunsets." DE LA RUE describes the indigo of the heavens as "shading through a sepia tint into red and orange," but does not state whether red or orange was uppermost. PIOLA describes the blue violet of the sky as passing into red without any gradation of colour.

In no case are the clouds described as *suddenly* changing colour from red to orange, or *vice versa*. HEATH speaks of the bright tints as gradually fading; and HOBBES says that the colours deepened as the eclipse grew.

* Query, also Galen in 1851.

SAMUELSON and RANYARD describe the red colour upon the clouds as fading away after totality, and not as being succeeded by orange, as would have been the case according to the direct illumination theory.

The similarity of the tints to those of sunset or sunrise seems to have struck most of the observers.

The following are only a few of the very numerous observations which might be collected on this subject.

M. Piola. LODI, 8th July, 1842.

"Annuaire pour 1846, du Bureau des Longitudes," p. 294.

A copper-red belt of light on the horizon 15° to 20° high; above, and without any gradation, a violet blue sky.

Au moment de l'éclipse totale, M. PIOLA voyait à l'horizon, vers le nord et vers le midi, une ceinture de 15 à 20 degrés de hauteur, dont la couleur ressemblait à celle du cuivre rouge. Plus haut, et sans dégradation aucune, le ciel était d'un azur violacé très-sombre.

Mr. Dunkin. CHRISTIANIA, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., p. 14.

Immediately below me was the Fiord dotted with its numerous islands. Over this mixture of land and water the effect of the darkness was very peculiar, the water having the colour of a deep purple, and the islands a dusky yellow. From my position every part of the visible sky was covered with cloud, but the density in different parts was very different; this had the effect of making some parts of the heavens terribly black, while others were comparatively brighter. There had been for some minutes a very black cloud under the sun, while immediately above him the clouds were formed of thin cirro-stratus; the effect of the contrast between the densely-blackened mass and the comparative brightness on the other side of the sun I shall never forget. Near the horizon, in the S.W., S., and S.E., the clouds were of a dark yellow colour; but in the north, where small portions of the sky were free from cloud, there was a purple hue.

Sir G. B. Airy. HILL NEAR GÖTTENBURG,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 7.

[Towards the end of totality] the clear sky [to the north] was strongly illuminated, to the height of 30° or 35°, and through almost 90° of azimuth, with rosy red light shining through the intervals between the clouds.

Dr. P. van Galen. TRAHERYD, SWEDEN,
28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 55.

Unmittelbar nach der Formirung des Lichtkranzes wurde eine Schichte Wolken, die sich stationär im Westen von Venus, nahe am Horizont befand, mit einer röthlich-violetten Farbe übergossen. Dieses überaus wundervolle Schauspiel, welches uns alle in Entzücken setzte, so dass jeder versicherte, nie etwas Schöneres gesehen zu haben, dauerte volle 3 Minuten.

Reddish-violet coloured cloud seen immediately after the beginning of totality near the horizon: it remained visible for 3 m.

Dr. Busch. RIXHÖFT,
28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 233.

Indem ich einige Notizen aufschrieb und das Auge vom Fernrohre abwandte, bot sich demselben, in der ganz unerwarteten Farbenpracht des Himmels, ein überraschender Anblick dar, der mich unwiderstehlich hinzog, mehrere Sekunden hindurch mit blossen Augen das nie Gesehene und nie Geahndete zu schauen. Grosse, mit dem Horizonte parallel laufende Strichwolken schienen sich mit dem Verschwinden des letzten Lichtfunkens plötzlich gebildet zu haben, die theils violett, theils braunröthlich gefärbt, einen Hintergrund zeigten, der im reinsten gesättigsten Gelb glänzte, und der ganzen Gegend eine Beleuchtung gaben, die weder mit der schönsten Morgen noch Abenddämmerung einen Vergleich aushält.

Violet and red-brown clouds on yellow background—similar to sunrise or sunset.

Prof. Stephen Alexander. LABRADOR,
18th July, 1860.

"Report of the United States Coast Survey for 1860," Appendix 21.

(p. 17.) Just before the total obscuration, Mr. Henry observed that the clouds in the region of the sun were of a copper colour, and when

the total obscuration had taken place we may gather from the various descriptions in the appended reports that the clouds at a considerable altitude had a leaden colour, while nearer to the horizon, and especially in the regions north and south which seemed to be beyond the dark shadow, red and a beautiful orange colour were predominant, the rich orange being most conspicuous near to the horizon, and the red towards the north.*

"The redness of the horizon," says Dr. BARNARD, "was remarkable in the north, chiefly perhaps because the north was the only point of the compass which furnished an horizon down to the sea. Looking in that direction, the appearance was very like what we see nightly at about eleven o'clock."

Mr. LIEBER speaks of the clouds to the east as being purple.

Lieut. ASHE says, "The light is totally different from that of morning and evening."

Mr. J. Buckingham. CAMMESA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

About half a minute after the commencement of totality, I observed that the south horizon was a bright bronzy yellow, and lurid just above, like some sunsets but brighter. The near upper clouds were greenish grey, while those lower were black with yellowish edges. A few seconds afterwards I noticed a compressed mass of clouds (a mackerel sky) about 3° in diameter; each small cloud of the mass was blushed on its centre with a splendid pink, fading off into delicate greenish white at the edges. About 45° to 50° S.W. of the moon was another similar mass.

Mr. R. F. Heath. PEÑA DE CASTILLA, SANTANDER,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

The sun was hidden by cloud during the whole of totality. My attention was chiefly occupied in watching the colouring of the broad belt of

* The observers were to the south of the centre line of totality.

clear sky on the horizon stretching right along the sea from N.W. to N.E. As darkness gradually came on, this was of an intense blue, varied only by one streak of fleecy cloud (as I presume); at the commencement of totality, this gradually assumed the golden tints of sunset, streaked with orange and red, while in the N.E. the belt was of the morning grey. At the time of perfect obscuration, the colours of this belt reflecting themselves in the water were gorgeous beyond all description. Gradually the bright tints faded, and the blue sky reappeared.

Mr. R. J. Hobbes. NEAR SANTANDER, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

As totality approached, a yellow glare deepening as the eclipse grew appeared to prevail in the east and north-east.

Mr. E. J. Lowe. FUENTE DEL MAR, SPAIN, 18th July, 1860.

Letter to the Editor of the "Times," published 25th July, 1860.

Before totality commenced the colours in the sky and on the hills were magnificent beyond description. The clear sky in N. assumed a deep indigo colour, while in W. the horizon was pitch black (like night). In the E. the clear sky was very pale blue with orange and red like sunrise, and the hills in S. were very red. On the shadow sweeping across, the deep blue in N. changed like magic to pale sunrise tints of orange and red, while the sunrise appearance in E. had changed to indigo. The colours increased in brilliancy near the horizon; over head the sky was leaden.

Mr. G. H. James. ST. LORENZO MOUNTAIN, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

I estimate that we were at a height of about 6,150 feet above the sea. To the west we had a view of the horizon which, during totality, had the appearance of a beautiful sunset; elsewhere we were surrounded by clouds, which shut out the surrounding country.

Mr. W. Beck. MIRANDA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

The last bright spot disappeared and the eclipse was total. The N.W. and S.E. were shrouded in pitchy darkness, indicating the direction of the shadow's length. The N. and E. glowed with a lurid fiery red like the top of an oven, across which jet black clouds floated, and against which the hill tops were seen in vivid relief. For some seconds after totality the southern and western sky presented a glorious appearance. The observer seemed to be gazing from out a dark cave filled with heavy tawny vapours, into an unfathomable sea of pale blue of the most delicate tint, in whose depths clouds of the brightest orange sailed, their colour being heightened by contrast. This effect quickly passed and the heavens in those quarters assumed the colour predominant in the north. In the zenith the sky was of an intensely deep indigo, over which reddish yellow clouds passed.

J. Bonomi. MIRANDA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

Totality. Dark towards the W., clouds towards the E. Yellowish red sky at the horizon where clear. Dark purple clouds near the mountains to the E. and W. Sky yellow red all round the horizon where no clouds. Clouds to the S.W. edged with dark.

Mr. Joshua R. Roberts. MIRANDA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

Around the horizon there was a wide band of various shades of vivid red light.

Mr. F. M. Willdon. HILL NEAR MIRANDA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

There was a regular belt along the horizon where the illuminated sky beyond the range of the obscurity reflected an orange golden light.

Mr. R. Reynolds. ORDUÑA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

To the north, on the edge of the shadow where the clouds had lifted a little from the tops of the hills in the extreme distance, the clear sky was of a coppery lurid red.

Mr. F. Simon. ORDUÑA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

A great mantle seemed suddenly to be thrown over the earth, just allowing a slight glimpse of light to peep in here and there through its corners on one side only. These patches of light, somewhat resembling sunset through a thunderstorm, were visible from near due east to about south-east.

Henry Vignoles.
O. J. Vignoles.
J. N. Shoolbred.
T. V. Crondace.

AMURRIO, SPAIN, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

In the far north-west a few streaks of coppery red were visible.

Dr. Winnecke. HILL OF SANTA MARINA, 3 MILES FROM POBES, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

About a quarter of an hour before the beginning of totality, I was struck with the singular dusky yellowish red colour of the sky near the horizon in the north-west.

Mr. Warren De La Rue. RIVABELLOSA, 18th July, 1860.

The "Times," August 9th, 1860.

The deep indigo of the upper part of the sky shading through a sepia tint into red and orange as it approached the horizon, etc.

Sig. Mantesino. THE HEIGHTS OF BANDERAS, NEAR BILBAO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

A few moments before the totality, a streak of bright sky was to be seen, as if the dawn of morning over the sea, from the N.W. to N.E. as far as we could see; but as the sun disappeared, the sky, and specially the clouds in that direction, and particularly to the N.W., became of a dark purple colour.

Sir G. B. Airy. HILL ABOVE HEREÑA, 18th July, 1860.

"Monthly Notices," Vol. xxi., p. 10.

Above the mountains in the distance, to the height perhaps of six or eight degrees, and especially remarkable on the north side, was a brilliant yellow or orange sky, without any trace of the lovely blush which I saw in 1851.

Lady Airy. HILL ABOVE HEREÑA, 18th July, 1860.

"Monthly Notices," Vol. xxi., p. 15.

[During the totality] the range of southern hills was of an inky black, while the sky beyond them was an intense golden orange. I have often seen a similar though much fainter effect in watching a fine summer sunset from the Greenwich Observatory through the smoke of London, when the air has been dry and the smoke very thin.

Prof. Grant. PEÑA CERRADA, SIERRA DE TOLOÑO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

When the sun was reduced to a very slender crescent I withdrew my eye from the telescope, and observed the appearance of the heavens. In the region whence the shadow was travelling the sky appeared black as pitch; in the opposite region it exhibited towards the horizon a dull orange hue.

Capt. W. S. Jacob. PEÑA CERRADA, SIERRA DE TOLOÑO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

A glance at the horizon during the obscuration showed a deep orange tint reaching nearly 10° in height, against which the distant hills showed of a purplish black, and the low clouds of a dirty green like tarnished brass.

The Rev. J. J. S. Perowne. ALI, NEAR VITORIA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

Just before the totality the sky in the horizon on the south-west, where an opening between the ranges of the mountains permitted us to see it, was of the brightest orange colour conceivable.

The Rev. H. S. Atwood. LA GUARDIA, NEAR LOGROÑO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

Our position, from its commanding height and almost uninterrupted view towards the east, allowed us to witness, about a minute before totality ceased, a strikingly beautiful sight of what had all the appearance of a bright yellow sunset in the *East*, occasioned by the "shadow path" having here passed away, leaving the mountain tops and far distant horizon gilded by the sun's rays, while we were still shrouded in gloom.

The Rev. R. A. Thompson. TUDELA,
18th July, 1860.

The "English Churchman," 26th July, 1860.

A bright light, I think of a greenish yellow colour, skirted the horizontal sky, and the banks of cumuli shone with a brilliant glow.

Herr Geo. Rümker. CASTELLON DE LA PLANA,
18th July, 1860.

"Die Totale Sonnenfinsterniss am 18 Juli, 1860," 4to, Hamburg, 1861.

The lower part of the heavens yellow or sepia, and on the horizon red.

(p. 6.) [During the totality the upper part of the sky was indigo while] die tieferen Theile eine gelbliche, vielleicht besser gesagt sepia, Farbe annahmen, und der Horizont selbst in S.W. gerothet erschien.

Mr. Burr. HIGHBURY, NEAR LONDON,
18th July, 1860.

"Monthly Notices," Vol. xxi., p. 25.

During the time of the greatest obscuration, the clouds on the horizon had a copper-coloured tinge. By 3 h. 5 m. this effect had quite passed away.

The Rev. W. R. Dawes. HADDENHAM, BUCKS,
18th July, 1860.

"Monthly Notices," Vol. xxi., p. 26.

About the time of the greatest obscuration a very thin cloud near the sun to the south displayed extraordinarily vivid prismatic colours.

Governor Pope Hennessey. BARRAM POINT, BORNEO,
18th Aug., 1868.

"Proceedings of the Royal Society," Recess, 1868, p. 85.

The line of round white clouds that lay near the horizon changed their colour and aspect with great rapidity. As the obscuration took place they all became of a dark purple, heavy looking, and with sharply defined edges; they then presented the appearance of clouds close to the horizon after sunset. It seemed as if the sun had set at the four points of the horizon.

Mr. Naftel. JERES, SPAIN,
22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

From the first second of contact I watched with all the attention I could command for any change in the effect on the landscape and sky.

The sky might then be described as dull, not particularly dark, with small light clouds passing rapidly across, the general tone being inclined to violet-grey. No change took place till within a few seconds of totality, when the light very sensibly lessened.

At the first moment of totality, sudden darkness came on; dark purple clouds appeared on the horizon, with streaks of bright orange between them.* The distant town of Jeres, from white, became a dark rich hue.

After totality, the dark purple clouds were no longer to be seen; the golden streaks disappeared.

Mr. Penrose. NEAR JERES, SPAIN,
22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

Clouds were over the sun during the whole of totality. Towards the last, however, there was an opening towards the east, with a certain space of pale green-bluish sky. The colour of the opening differed from that of a portion of open sky under the circumstances of sunrise or sunset, inasmuch as there was an entire absence of rose colour and almost an entire absence of yellow. The prevailing tone was greenish white.

Immediately after the light reappeared I commenced putting colour to a sketch which I had already prepared in outline.

I also made a sketch looking west, with the effects of the reappearance of the light.

A little yellowish tone of light showed itself in a streak about W.S.W. as the light was near its reappearance.

Mr. Griffith. SYRACUSE, SICILY,
22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

Before the commencement of totality, and while the cloud was concealing the sun from our view, a remarkable appearance of colour was seen

* In a water-colour picture painted by Mr. Naftel soon after the eclipse (which is at present hanging in the council-room of the Royal Astronomical Society), the streaks between the clouds are bright orange above, and a coppery-red beneath, as in an ordinary sunset.

on the edge of a cloud about 6° or 7° from the sun towards the west. This lasted only for a few seconds, but several persons near me noticed that the tint was of a remarkable rose-colour. We were much struck by the beauty of the phenomena, and those who were acquainted with the colour of incandescent hydrogen were reminded of it in this instance.

Mr. H. Samuelson. NEAR VILLASMUNDA, SICILY, ABOUT 8 MILES S.W. FROM AUGUSTA, 22nd Dec., 1870.

"Nature," Feb. 16th, 1871, p. 311.

As soon as the moon passed off from the sun's face, and for some seconds after totality had wholly ceased, the clouds in the S.E. were suffused with deep red copper colours, which gradually faded away as the sun regained his power.

Mr. Ranyard. NEAR VILLASMUNDA, SICILY, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

Soon after totality our attention was attracted by bright red coppery colours upon a bank of cloud lying near the horizon to the S.E. These remained for some forty or fifty seconds, growing all the time less intense, and at the last faded into a dull grey. The Sappers also told me that the clouds towards the east were at one time of a bright yellow, which they described as canary-coloured, but whether this was before or after the end of totality they could not remember.

CHAPTER XXVII.

IRIDESCENT CLOUDS AND ARCS OF PRISMATIC COLOUR.

FIRST as to arcs of prismatic colour seen within a few degrees of the sun's place. With the exception of the coloured bows observed on the disc of the moon during totality by GILLISS in 1860, all the arcs described appear to have been arranged concentrically* about the sun.

Their radius has been estimated at from one to as much as five degrees. In some instances more than one concentric arc has been observed (BURTON figures four). In the only two cases where the order of colours in arcs about the sun is mentioned, the red end of the spectrum is described as being outermost. In GILLISS's observation the colours mentioned do not succeed one another in the order of the spectrum; the red it would seem from the description was on the concave side of the arcs.

Rainbow-tinted Arcs near Sun.

1858.	De Birto. D'Azambuja.	During totality.	Coloured circle described as a little outside the corona, red on the outside.
1860.	Gilliss.	During totality.	Two coloured arcs seen upon the dark moon each about 2′ broad.
	Quetelet.	Uneclipsed sun.	Two iridescent arcs estimated at 4° to 5° in radius.
1868.	Sharp.	Just after totality.	A narrow rim of shaded colours surrounding the moon's disc.
1870.	Burton.	Shortly before totality.	A series of coloured bows (2° to 3° in radius).

* Padre Cappelletti, who observed the eclipse of 25th April, 1865, in Chili, has given a drawing of a crescent-shaped halo about the eclipsed sun. A woodcut from this drawing is given in Padre Secchi's "Le Soleil," p. 155.

Corallo. Secchi.	During totality.	(Colour seen on corona.)
Pistoia.	During totality.	Circular iris, red on the outside, about 3 in radius.
Brothers. Fryer.	Before totality.	Rainbow tints regularly disposed, a few diameters from the sun.

The following observations of prismatic colours upon clouds seem also to be connected with the above.

Iridescent Clouds seen near to the Sun.

1860.	Dawes.	About the time of greatest obscuration.	Cloud near sun displayed vivid prismatic colours.
1870.	Brown.	During totality.	Certain clouds 3° from moon appeared more illuminated than others.
	Adams.	Three minutes before totality.	Brilliant patches of red and yellow on a cloud near to the sun.
	Secchi.	Before, during, and after totality.	Iridescent cloud near sun.
	Griffith.	Before totality.	Red cloud near sun.

In addition to the prismatic colours seen near the sun iridescent clouds are described at greater distances, varying from 15° to 50° from the sun's place, but we have found no record of arcs of colour being seen at such distances.

Iridescent Clouds which are not described as in the immediate vicinity of the Sun.

1748.	Monnier.	After the middle of the eclipse.	Rainbow colours upon clouds below sun (distance from sun not mentioned).
1858.	De Birto.	During totality.	Rainbow colours on cloud 25° to W. of sun.
1860.	Buckingham.	During totality.	Two masses of coloured clouds, one 6° or 8° below the moon, the other 45° to 50° S.W. of the moon.
1870.	Hardy. Winwood.	Before the central epoch (not total).	Coloured patch 15° E. from sun, 30° broad and 60° long.

It will be noticed that both rainbow-tinted arcs and iridescent clouds have been observed not only during the period of totality, but also before and after the total phase, as well as at stations situated at a considerable distance from the path of totality.

M. Monnier. ABERDOUR CASTLE, SCOTLAND, 14th July, 1748.

"Phil. Trans.," Hutton's Abridgment, Vol. ix., p. 591.

A little after the middle of the eclipse some clouds that seemed stationary below the sun appeared tinged on their upper extremities with all the colours of the rainbow.

M. de Birto.
M. d'Azambuja. PINHEIROS, PARANAGUÁ, 7th Sept., 1858.

"Astr.. Nachr.," Vol. xlix., p. 287.

Circular rainbow seen around the eclipsed sun, red on the outside. Apparently no cloud in front of the sun, coloured cloud at 25° W. of sun.

Nous passons maintenant à un phénomène tout-à-fait nouveau et très digne de remarquer, observé à Pinheiros par M. DE BIRTO et à la station centrale par M. D'AZAMBUJA. Il s'agit d'un cercle coloré présentant les couleurs de l'arc-en-ciel, et qui entourait la couronne. D'après M. D'AZAMBUJA ce cercle était un peu en dehors de la couronne. Les contours étaient faibles et le rouge occupait le bord extérieur. Le phénomène a été vu à l'oeil nu; dans la lunette il était à peu près insensible d'après M. D'AZAMBUJA. Cette apparence, serait-elle le phénomène météorologique ordinaire de la couronne qui entoure le soleil et la lune quand de légères vapeurs vésiculaires les recouvre?

L'état de pureté du ciel à la station centrale dans la région du soleil présente des difficultés à cette explication.* On pourrait, au contraire, invoquer en sa faveur la remarque, faite par M. DE BIRTO, qu'un nuage estimé à 25° à l'occident du soleil s'est coloré des mêmes teintes. Cette position, en admettant une très-légère erreur sur l'estime, correspond en effet à la position du parhélie.

* In all the other observations given in this chapter light clouds appear to have been present.

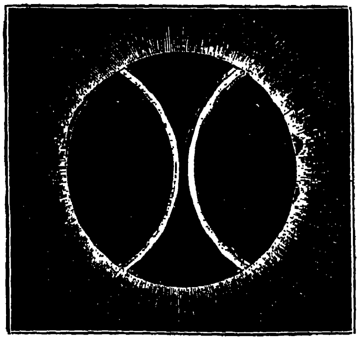
Lieut. J. M. Gilliss. STEILACOON, WASHINGTON TERRITORY, 18th July, 1860.

"United States Coast Survey Report for 1860," Appendix No. 22, p. 11.

[Towards the latter end of totality] I again lifted my face towards the telescope, and in so doing a most extraordinary scene was apparent. A totally different picture had been substituted for the black disc which only a few brief instants before was seen circled by a tremulous band of vermilion or red, and yellow lights, overlapped by the solar clouds. True, the disc was there, but it was thrown in bold relief upon a ground of virgin white, traceable in every direction for the distance of quite a semidiameter. The solar clouds were there also, but the gorgeous circlet was gone, and over the jetty surface colours of the spectrum apparently flashed in circular bands of equal diameter with the moon.

A spectacle so remarkable thoroughly startled me from the equanimity with which the preceding phenomena had been observed, and I was irresistibly drawn to its contemplation, to the neglect of changes that might have been taking place in the borders of the solar clouds and corona.

As near as it was possible to estimate them, each band or circular segment was about 2′ broad. Its colours were crimson or red, violet, yellow, and green, the last one being on the edge over the lunar centre, and of a tint not darker than that known as pea-green. The bands of red and green were wider than those of violet and yellow.



They were not visible beyond the borders of the moon, and as each seemed to be in rapid revolution downward towards the lunar centre, their relative places appeared to be incessantly changed, like those of a kaleidoscope, more closely than anything else with which I can compare them.

They continued visible with the telescope at least 10 s. longer, and vanished with the first appearance of the sunlight beyond the western limb of the moon. The figure is intended to represent the phase of the eclipse just described. The proportions and angles of position are correct, as seen in an inverting telescope, the upper points of the discs being south.

The illustration has been prepared by Mr. McMURTRIE, U.S. Coast Survey, from my rough sketches and verbal account. The dimensions and places of the filaments composing the coloured circles are intended as illustrative of the general appearance and not as a photograph of the actual picture.

Mr. J. Buckingham. CAMMESA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

About 6° or 8° below the moon [Nearly a minute after the commencement of totality] I noticed a compressed mass of clouds (a mackerel sky) about 3° in diameter—each small cloud of the mass was blushed on its centre with a splendid pink, fading off into delicate greenish white at the edges. About 45° to 50° S.W.* of the moon was another similar mass of cloud, tinted a fine green in their centres, fading to light pinkish at the edges. I compared them at the moment to a quantity of loose rose petals. In a few seconds (fifteen to twenty) they appeared to fade entirely away. Mr. WARING was observing on their singularity, when happening to look again I observed them to have reappeared in the precise situations, but exactly complementary in colour. The clouds lost their colours as they changed their positions, and those entering on the former positions took them.

The Rev. W. R. Dawes. HADDENHAM, BUCKS,
18th July, 1860.

"Monthly Notices," Vol. xxi., p. 26.

About the time of the greatest obscuration a very thin cloud near the sun to the south displayed extraordinarily vivid prismatic colours.

* In Mr. Buckingham's original notes, this runs "about 45° to 50° S.W. of the moon, and a similar distance, or rather more, perhaps 9° or 10°, another similar mass of cloud etc.," as if the "45° to 50°" referred to the angular position of the mass of clouds, and not to its distance from the eclipsed sun.

Prof. E. Quetelet. BRUXELLES, 18th July, 1860.

"Astr. Nachr.," Vol. liv., p. 6.

Two circular iridescent arcs of 4° or 5° radius around the uneclipsed sun.

A 2 h. 49 m. temps moyen on a remarqué autour du soleil l'apparition de 2 arcs irisés; le plus brillant, à gauche et un peu au-dessus du centre du soleil, présentait les 7 couleurs principales; l'autre, où l'orange et le vert dominaient, était à droite. Ce phénomène s'est présenté au moment où une couche de cirrus passait devant le soleil. Le rayon de ces arcs a été estimé de 4 à 5 degrés environ.

Rev. John Sharp. MASULIPATAM, 18th Aug., 1868.

"Report of the Government Astronomer upon the Observations of the 1868 Eclipse," p. 22.

The first break of restored sunlight seemed intensely bright, and just after the reappearance a narrow rim of shaded colours, mixing from red to yellow on the west, and merging into blue and purple on the south, appeared to surround the moon's disc on those sides.

Lieut. Alex. B. Brown. MARIA LOUISA OBSERVATORY, 22nd Dec., 1870.

"Monthly Notices," Vol. xxxi., p. 59.

Some of the highest clouds, at some 3° or more apparently from the moon, seemed to be more illuminated by the light of the corona, leucosphere, and prominences, than those in other places.

Commander Hardy. SION HILL, BATH,
Rev. H. H. Winwood. 22nd Dec., 1870.

"Monthly Notices," Vol. xxxi., p. 183.

A few minutes—three or four as nearly as I can remember—before the central epoch, the attention of Mr. WINWOOD and myself was drawn to a coloured patch, which appeared at the distance eastward from the sun of about 15°, and which seemed to be stationary. The space occupied by it might be, from its margin nearest the sun, about 30° towards the east, and

spreading to double that angular space N. and S. The marginal portions next the sun presented a lively ruddy tint, then melting into an orange tint, blended with green and dark purple in succession, proceeding eastward, and to the N. and S. Green, however, was the prevailing tint, and covered a much larger space than the others. Indeed, it seemed to be everywhere in the patch mixed with them, and to give them a muddy hue. These colours attained their greatest vividness about the time of the central phase of the eclipse. It soon after began to fade in brightness, but to become more dark, especially towards the south-west.

Prof. W. G. Adams. AUGUSTA,
22nd Dec., 1870.

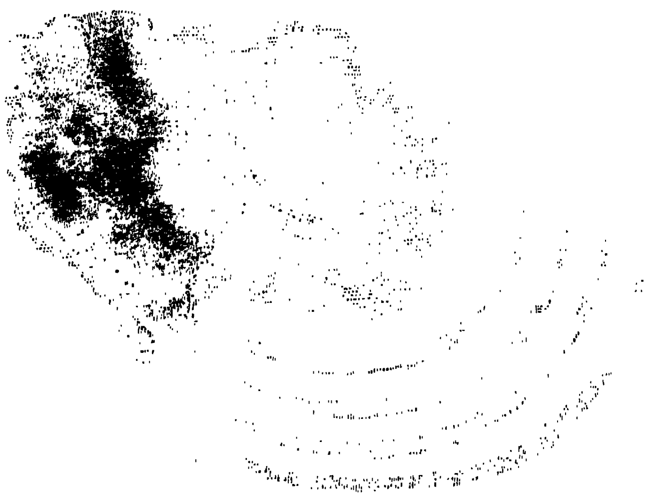
"Monthly Notices," xxxi., p. 160.

About three minutes before totality there were brilliant and very remarkable patches of red and yellow light on a cloud to the right and rather below the sun.

Mr. Burton. AUGUSTA,
22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

Shortly before totality, a series of coloured bows appeared in the thin cirro-cumuli covering the sun and the sky round its neighbourhood.



The bows were below the sun, and apparently parts of circles concentric with the sun.

I did not notice any unusual colours on objects.

I think that I have drawn the arcs in the accompanying diagram rather too short, the deficiency being chiefly at the eastern extremity.

Arciprete Corallo. AUGUSTA, 22nd Dec., 1870.

"Rapporti della Commissione Italiana," Padre Secchi's Report, p. 23.

Drawing made by Corallo in which regions of iridescent cloud are indicated.

Il signor Arciprete di Augusta Can. CORALLO fece un disegno della corona, che credo utile di qui soggiungere . . . . Vi è indicata pure la regione iridata delle nubi.* Mons. CORALLO uso un binoculo di ottima condizione, nel fare questo disegno.

[Padre Secchi also says, p. 24:]

Iris seen also by P. Secchi and others.

Questa Iride la vidi anch' io, e fu veduta in molti siti, e ciò spiega le iridi vedute dal P. CAPPELLETTI al Chilli.

Capt. Pistoia. AUGUSTA, 22nd Dec., 1870.

"Rapporti della Commissione Italiana," p. 24.

Circular iris, concentric with sun, visible during totality; red inside, blue outside; diameter of iris about 6°.

Quando fu oscurato il Sole, e la nube corse a coprirlo, al disotto di esso si vide una bella Iride; il rosso era molto più distinto. L' Iride era circolare, simmetrica al Sole. Il bleu dentro, il rosso fuori, sotto. L' Iride era separata dal Sole di un terzo della larghezza dell' Iride stessa, e l' Iride poteva avere un diametro di 12 volte quello del Sole.

Padre Secchi. AUGUSTA, 22nd Dec., 1870.

"Rapporti della Commissione Italiana," p. 20.

Iridescent clouds seen near the sun during, before, and after totality.

Tranne qualche istante in cui levai l' occhio dal cercatore per guardare quell' infausta nube, non mi distrassi in altra cosa veruna. Però vidi allora l' orizzonte tutto colorato di vivo color giallo come nell' aurora di un giorno nuvoloso, e molte nubi iridate nelle vicinanze del Sole che si erano vedute già anche prima e si videro appresso dopo ricomparso il Sole anche più belle.

* No *arcs* of prismatic colour are indicated in the drawing, but the words "bianco," "rossastro sfumato," "verde sfumato," are written upon different parts of the corona. The following note is also added to the drawing: "L' iride sottoposta apparve nei momenti della totalità dell' ecclisse; i fili estremi erano tinti di un rossastro sfumato, che l' imbruniva. La parte vicina al sole, già ecclissato, era biancastra alquanto lucida, la parte media era verdastra sfumata, che defilata coloriva i fili medî dell' iride."

Mr. Brothers.
Mr. Fryer.

SYRACUSE,
22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

The beautiful thin crescent of the sun, in shape like the new moon, came into view and seemed to sail rapidly among the now thinning clouds. A most lovely sight at this time presented itself: the thin edges of the cloud a few diameters below the moon appeared to be broken up into small flakes, and each flake looked as if observed through a prism, being adorned with rainbow tints regularly disposed.* These were pure and brilliant, and presented a more splendid sight as the other light over earth and heaven was dying away.

* See also the observation of Mr. Griffiths in the chapter on "Colours on Clouds," where apparently the same clouds are described as red.

CHAPTER XXVIII.

COLOUR OF THE SKY.

Before totality and when the sun is only about five-sixths covered, the colour of the sky in the zenith, and down to a distance of some ten or twenty degrees above the horizon, begins sensibly to change. From the ordinary blue of full daylight it gradually assumes a darker hue, which has been variously described as purple black, violet, azure, and indigo, thus :—

Colour of the Sky before Totality.

1715.	**Halley.**	Sun 10 digits covered.	Sky changed to a dusky livid colour, having an eye of purple intermixed.
1836.	**Henderson.**	Annular eclipse.	Sky inclined to a purple hue.
1836.	**Smyth.**	Nearly annular.	Atmospheric light became mellowed, deepening to a peculiar lurid gloom.
1851.	**Airy.**	Before totality.	Clear blue sky became purple black.
	Hind.	Before totality.	Azure blue sky changed to deep violet.
1858.	**Liais.**	Some minutes before totality.	Yellow seemed to predominate in the spectrum of daylight.*
1860.	**Barnard.**	Just before totality.	Sky much darker, still purely blue.
	Winter.	Before totality.	Sky turned to a dark olive.
	Reynolds.	Before totality.	Blue sky became purple.
	Perowne.	Before totality.	Sky had a dead leaden appearance.
	Perry.	Before totality.	Sky became almost black.
	Rümker.	Before totality.	Light blue sky became a dark "Blaugrau."
	Hind.	11 m. before the greatest obscuration in England.	Sky appeared duller or more of an indigo blue.
	Burr.	During the time of the greatest obscuration in England.	Sky near zenith of a deep indigo hue.

At the moment of totality the suddenly altered conditions of illumi-

* The part of the heavens to which the spectroscope was directed is not mentioned.

nation * give rise to a further change of colour, which is so striking that few observers fail to notice it. We have given only a selection from these observations.

The heavens in the zenith according to WEEDEN appear to hang "low down as it were in the shape of a watch glass." McLEOD describes them as "hanging down from overhead" like a blackish blue hemispherical cover. The illumination increases towards the horizon, and the violet canopy of sky is there fringed with orange and red.

Observations of the comparative brightness of the different parts of the upper heavens are rare. BUCKINGHAM says that the sky towards the central shadow was black. OOM, that the purple blue ground of the heavens was brightest near to the corona. EASTMAN, that the darkest portion of the western sky was "just outside the bounding lines of the corona." And S. PEIRCE that the sky was not brighter near to the corona.

The colour of the heavens, which no doubt depends greatly on the atmospheric conditions at and around the observer's station, has been variously described as purple, indigo, slate colour, olive, and deep violet like the colour of the spectrum near H. Thus,—

Colour of Sky during Totality.

1842.	Piola.	Azur violacé très-sombre.
1860.†	Buckingham.	Sky overhead deep violet to indigo, towards the central shadow quite black.
	Wray.	Changed to greenish olive brown and deep purple in succession.

* It will be seen from the chapter on the "Brightness of the Horizon," that it is probable that the chief illumination of objects within the area of totality, is derived from the bright sky and clouds upon the horizon. The lower part of the atmosphere within the area of the moon's shadow would therefore be illuminated by light which had passed through many miles of atmosphere near to the earth's surface, which would thus have lost much from the violet end of its spectrum. The particles floating in the lower atmosphere would therefore disperse a ruddy light. Higher up the light illuminating the atmosphere would be less and less ruddy, and the area of cloud beyond the moon's shadow by which it would be lit up will be greater and greater as we ascend. An observer looking upwards during totality might therefore expect to see a ruddy tinge from the lower atmosphere projected on a deep blue, similar to, though probably even darker than, the deep blue of the heaven's as seen from a high mountain—a combination of colour which would very well be described as purple or violet.

† The brackets signify that the observers were at the same station.

	Janson.	In zenith purple.
	Winter.	Dark olive.
	Roberts.	Exceedingly dark indigo.
	Weeden.	Heavens like a dark purple canopy hanging low down, as it were in the shape of a watch glass.
	Reynolds.	Blue sky became purple and deepened nearly into black.
	Winnecke.	Bluish violet.
	De la Rue.	Deep indigo.
	Oom.	Heavens purple blue, brightest near corona.
	Goldschmidt.	" Schwarzblau " as on a fine summer night.
	Rümker.	Sky changed to a " schwärzlichem Indigo."
1869.	**Curtis.**	Sky was not clear; leaden bluish grey.
	Eastman.	Sky slate colour, darkest portion just outside the bounding lines of the corona.
	McLeod.	Sky like a blackish blue hemispherical cover hanging down from overhead.
	J. M. Peirce.	Violet blue.
	S. Peirce.	Dark purplish blue, not darker near the corona.
1870.	**Lindsay.**	Very deep purple.
	Ranyard.	Deep violet somewhat like the colour of the spectrum near H.

Dr. Edmund Halley. ROYAL SOCIETY'S HOUSE, CRANE COURT, LONDON,
22nd April, 1715.

Hutton's "Abridgment of the Phil. Trans.," Vol. vi., p. 154

From this time the eclipse advanced, and by 9 o'clock it was about ten digits, when the face and colour of the sky began to change from perfect serene azure blue to a more dusky livid colour, having an eye of purple intermixed, and grew darker and darker till the total immersion of the sun, which happened at 9 h. 9 m. 17 s. by the clock.

Mr. Henderson. OBSERVATORY, EDINBURGH,
15th May, 1836.

" Memoirs of the R. A. S.," Vol. x., p. 38.

Although my attention was almost completely engaged in my work it was impossible not to take notice of the considerable diminution of daylight which took place towards the middle of the eclipse,* and of the

* The eclipse was nearly annular at Edinburgh.

unusual and unnatural colour which the sky assumed, inclining to a purple hue.

Admiral Smyth. BEDFORD, 15th May, 1836.

"Cycle of Celestial Objects," Vol. i., p. 143.

As the sun obfuscated the air sensibly cooled, the atmospheric light became mellowed, deepening to a darkness which bore no resemblance either to morning or evening twilight; and at the greatest* obscuration assumed the peculiar lurid gloom which commonly heralds in a summer thunder-storm.

M. Piola. LODI, 8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 294.

Plus haut [M. PIOLA has just described the colour of the horizon during totality] le ciel était d'un azur violacé très-sombre. Sky above dark blue violet.

Sir G. B. Airy. HILL NEAR GÖTTENBURG, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 5.

[During the approach of totality,] a patch of clear blue sky in the zenith became purple black while I was gazing at it.

Mr. Hind. RÖEVELSBERG, NEAR ENGELHOLM, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 84.

The sky where clear had gradually changed from an azure blue to a deep violet.

* When the eclipse was at its greatest a segment of the sun remained, equal in depth to about one-fourth of the solar diameter.

Dr. Emmanuel Liais. PARANAGUA, 7th Sept., 1858.

"Astr. Nachr.," Vol. xlix.

Spectrum of sky examined just before totality—yellow part of spectrum found to predominate.

(p. 281.) Vers 10 h. 55 m. (quelques minutes avant l'obscurité), M. LIAIS examina les raies du spectre fourni par la lumière du jour, et il y chercha spécialement les changements qu'il avait remarqué dans l'éclipse du 15 mars. Il ne vit pas le grand affaiblissement de la lumière violette qu'il avait noté alors, mais il trouva que la lumière jaune devenait plus prédominante qu'au commencement du phénomène. Les raies d'ailleurs n'avaient pas varié.

Dr. F. A. P. Barnard. AULEZAVIK ISLAND, 18th July, 1860.

"United States Coast Survey Report" for 1860, Appendix No. 21, p. 23.

Just before the total immersion I once more noticed the tint of the uncovered sky, and found its darkness greatly increased. It was still purely blue, but with a depth of azure almost equal to that of the ocean.

Mr. J. Buckingham. CAMMESA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

About half a minute after the commencement of totality the sky overhead was deep violet to indigo, and to the northward towards the central shadow quite black.

Mr. Wm. Wray. CAMMESA, NEAR AGUILAR, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

As the shadow approached, the deep blue sky changed to greenish olive brown and deep purple in succession.

Mr. T. C. Janson. BURGOS,
18th July, 1860.

MS. Reports of the Himalaya Expeditions.

During totality the sky in the zenith was of a purple hue, while at the horizon over the public walk by the river it was of a dark orange colour.

Mr. R. Winter. MOUNTAIN OF SAN LORENZO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

Before totality the azure of the sky turned to a dark olive. . . . . . . During the totality the sky retained its dark olive colour except at the horizon, where there was a narrow band of light of a dusky yellow colour. Our observing station was about 6150 feet above the level of the sea.

Mr. Joshua R. Roberts. MIRANDA DE EBRO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

We were on the top of a hill about 1600 feet above the level of the sea. During totality the sky was of an exceedingly dark indigo colour, except around the horizon, where there was a wide band of various shades of vivid red light.

Mr. F. M. Weeden. HILL NEAR MIRANDA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

During totality the heavens seemed like a dark purple canopy, hanging low down, as it were, in the shape of a watch glass, and covering the earth, excepting in a regular belt near the horizon, where the illuminated sky beyond the range of the obscurity reflected an orange golden light.

Mr. Reynolds. ORDUÑA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

We were observing from the top of a hill about 1000 feet above the town. . . . . . . Southward a large space of blue sky became purple, and deepened nearly into black as the shadow swept over it.

Dr. Winnecke. HILL OF SANTA MARINA, 3 MILES FROM POBES, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The black disc of the moon was surrounded by a bright glory of quiet yellowish white light, on the bluish violet of the celestial vault.

Mr. Warren De la Rue. RIVABELLOSA, 18th July, 1860.

The "Times," August 9th, 1860.*

The deep indigo of the upper part of the sky, shading, through a sepia tint, into red and orange as it approached the horizon,—the deep blue of the mountains as contrasted with the orange sky, and the peculiar light cast on the spectators, impressed me with a feeling of solemnity, never to be effaced.

Lieut. F. A. Oom. ALTO D' URBANEJA, NEAR POBES, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

During the totality I devoted a few seconds to a general view of the magnificent spectacle. The corona appeared upon the purple blue ground of the heavens; this colour was brightest near the corona and increased in darkness with greater distances.

Herr Hermann Goldschmidt. VITORIA, 18th July, 1860.

"Astr. Nachr.," Vol. lvi., p. 308.

The heavens in the zenith dark blue, as on a fine summer night.

Die Farbe des Himmels im Zenith war schwarzblau, wie in einer schönen Sommernacht, was mit dem gelbgrünen Lichte am Horizont contrastirte.

* See also Bakerian Lecture in "Phil. Trans." for 1862, Part i., pp. 23, 24.

The Rev. J. J. S. Perowne. ALI, NEAR VITORIA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

As the time of the total obscuration approached, the sky, which in the zenith and in the neighbourhood of the sun was cloudless, had a dead leaden appearance, increasing in intensity every moment, whilst at the same time lower down where it touched the mountains it was comparatively light.

Mr. J. G. Perry. HILL OF CANTABRIA, NEAR LOGROÑO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

As the obscuration advanced, the sky in the unclouded parts became almost black; later, as the darkness of totality swept over the landscape, it left the sky in the north and west horizon of a yellowish green colour, such as I have seen after a violent thunder-storm.

Herr Geo. Rümker. CASTELLON DE LA PLANA, 18th July, 1860.

"Die Totale Sonnenfinsterniss am 18 Juli, 1860." 4to, Hamburg, 1861.

Sky of a dark indigo colour during totality—beneath, yellowish or sepia; and on the horizon, in S.W., red.

(p. 6.) Die gewöhnliche hellblaue Farbe der Luft (der spanische Himmel ist, wenigstens in den Sommermonaten, um nichts dunkler wie der unsrige) begann in der Höhe allmälich in ein dunkles Blaugrau überzugehen, welches sich während der Totalität zu einem schwärzlichen Indigo umwandelte, während die tieferen Theile eine gelbliche, vielleicht besser gesagt Sepia Farbe annahmen, und der Horizont selbst im S.W. geröthet erschien.

Mr. J. R. Hind. MR. BISHOP'S OBSERVATORY, LONDON, 18th July, 1860.

Letter to the Editor of the "Times," published July 19th, 1860.

At 2 h. 37 m. a large expanse of clear sky in the south was not of the ordinary tint, it appeared duller, or more of an indigo blue. At 2 h. 42 m., or about six minutes previous to the greatest eclipse, the deeper colour of the sky was very marked in a break N.W. of the zenith.

Mr. Burr. HIGHBURY, NEAR LONDON,
18th July, 1860.

"Monthly Notices of the R. A. S.," Vol. xxi., p. 25.

During the time of the greatest obscuration dense clouds covered the heavens. Near the zenith a few breaks showed the sky of a deep indigo hue.

By 3 h. 5 m. this effect was gone, and the sky between the clouds was then a pale blue.

Dr. Curtis. DES MOINES, IOWA,
7th Aug., 1869.

"Washington Observations," 1870, Appendix ii., p. 134.

The appearance of the sky was different from what I had expected, the colour being rather a leaden bluish-grey than the deep indigo generally observed where the atmosphere has been clear.*

Prof. Eastman. DES MOINES, IOWA,
7th Aug., 1869.

"Washington Observations," 1870, Appendix ii., p. 106.

I gave a few seconds' time to the observation of the peculiar light. Owing to my position in the observatory I could see only the western sky, in which the darkest portion was just outside the bounding lines of the corona. This portion of the sky had a dark slate colour, changing towards the south-west to a leaden hue, but maintaining its dark slate colour, with but little modification as far east and north as I could see. This dark colour prevailed in the sky west of the sun nearly down to the horizon.

Mr. R. A. McLeod. SPRINGFIELD, ILLINOIS,
7th Aug., 1869.

"United States Coast Survey Report for 1869," Appendix No. 8, p. 46.

The appearance of the sky was as if a blackish-blue hemispherical cover were hanging down from overhead, its rim reaching to within about 12° of the horizon. Between this rim and the horizon, to the north and as far around as I looked, the sky was of a dusky yellow.

* Dr. Curtis observed that there was a dense haze in the air. See p. 132.

Mr. J. M. Peirce. SPRINGFIELD, ILLINOIS,
7th Aug., 1869.

"United States Coast Survey Report for 1869," Appendix 8, p. 41.

During totality, the sky was of a violet blue above, while it was lurid near the horizon, at any rate in the north.

Prof. Charles S. Peirce. BARDSTOWN, KENTUCKY,
7th Aug., 1869.

"United States Coast Survey," Appendix No. 8 to Report for 1869, p. 14.

[During totality] the sky was of a dark, somewhat purplish, blue. It was not lighter near the corona.

Lord Lindsay. MARIA LOUISA OBSERVATORY,
22nd Dec., 1870.

"Monthly Notices," xxxi., p. 60.

At the time of totality the blue patches in the sky appeared of a very deep purple colour.

Mr. Ranyard. NEAR VILLASMUNDA,
ABOUT 8 MILES TO THE S.W. OF AUGUSTA, SICILY,
22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

Some ten minutes before totality we noticed that the sky along the horizon to the west* was of a bluish-green, much like the colour of the sky in stormy weather when seen beneath a bank of clouds in the opposite direction to the sun.

During totality the sky in the neighbourhood of the eclipsed sun (I did not look at the horizon) was of a deep violet, which reminded me somewhat of the colour of the spectrum near H.

* The region of totality approached the observers from their W.S.W., and passed away to the E.N.E.

CHAPTER XXIX.

APPEARANCE OF THE MOON'S DISC DURING TOTALITY.

PIERCE, SHALER, and WARINGTON SMYTH describe the moon as being darker than the surrounding sky. It should be remembered that any illumination due to our own atmosphere would stretch equally over the place of the dark moon, as well as over the area immediately surrounding the corona. The greater darkness of the moon must therefore either be due to a sense of contrast (the brighter layers of the corona being on the inside) or to a very widely spread outer corona.

Frau MÄDLER says that the appearance of the moon's disc was such that it gave her the idea that she was looking into a deep hole; and SECCHI describes the moon as appearing detached (staccata) from the background of sky.

To RICHARDS, PARSONS, and BREEN, the lunar limb seemed brighter than the central part of the disc; so that the moon had the appearance of being spherical.

At the time of a total eclipse the moon is lit up by full or nearly full earthshine,* yet none of the observers record that they were able to detect any of the lunar details, though many of them carefully examined the disc for that purpose. Thus,—

1842.	**Arago.**	Lunar details carefully looked for but not seen.
	Airy.	Moon distinctly visible as having independent light, but no details made out.
1851.	**Carrington.**	Could not perceive any light or shade on the moon's surface.
	Good.	No spot either dark or light perceptible.
	Dawes.	No striking variations of light observed on moon's surface.
	Mauvais.	No details perceived.
1860.	**Mädler.**	Moon uniformly black, no bright spots perceived.
1868.	**Walker.**	Could not detect a speck upon the moon.

* See note appended to Hudson's observation.

1870.	**Hudson.**	Moon had a green velvety appearance; lunar mountains not perceptible.
	Tupman.	Irregularities of lunar surface not observed.

GRANT speaks of the moon's disc as being of a dark purple hue eight minutes before totality, and BUCKINGHAM describes it four seconds before totality as dark olive. HIND says that at the beginning of totality it was decidedly reddish purple, but that before the end of totality it had assumed a dull purple colour. The estimates as to the tint of the moon's disc during totality vary greatly; thus,—

Colour of Moon's Disc during Totality.

1851.	**Pettersson.**	Greyish brown.
	Dawes.	Purplish black.
	Mauvais.	Black.
1860.	**Richards.** **Parsons.**	Lead coloured.
	Breen.	Dark grey.
	Janson.	Quite black.
1860.	**Madler.**	Deep black.
	Frau Mädler.	Deep dark blue.
	Secchi.	Inky black.
1868.	**Walker.**	Intensely black.
1869.	**C. S. Pierce.**	Purplish blue.
1870.	**Hudson.**	Green.
	Tupman.	Greenish grey.

It is perhaps worth the reader's while to compare the following judgments of colour with those made by the same observers as to the colour of the sky during totality.

		Colour of Moon's Disc.	Colour of Sky during Totality.
1851.	**Hind.**	Decidedly reddish purple at the beginning of totality, dull purple towards the end.	Deep violet.
1860.	**Buckingham.**	4 seconds before totality very dark olive.	Over head deep violet to indigo, towards the central shadow quite black.
	Janson.	Quite black.	Purple.
1869.	**C. S. Peirce.**	Deep dull, somewhat purplish blue, darker than the sky.	Purplish blue.

M. Arago. PERPIGNAN, 8th July, 1842.

" Annuaire pour 1846 du Bureau des Longitudes," p. 281.

The ashy light was completely blotted out by the atmospheric illumination; none of the lunar spots were distinguishable.

La lumière cendrée fut complètement effacée par la lumière atmosphérique. Malgré tous nos soins, nous ne parvînmes pas à distinguer une seule des taches de la Lune.

Sir G. B. Airy. CHURCH OF THE SUPERGA, NEAR TURIN, 8th July, 1842.

" Monthly Notices," Vol. v., p. 219.

I took off the dark glasses and carefully examined the moon with the telescope. Her disc was distinctly visible as having independent light, and I think that if it had been stronger, I might have seen the large tracts of different brightness on her disc. I could not, however, see the smallest inequality of light, of the nature either of broad dark tract, or dark spot, or bright spot. I looked carefully for a long time (in proportion to the whole duration of darkness), and am confident that there was nothing of this kind to be seen.

Lieut. C. A. Pettersson. GÖTTENBURG, 28th July, 1851.

" Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 69.

The dark disc of the moon, which was very dark, was of a greyish brown tint.

Mr. R. C. Carrington. LILLA EDET, 28th July, 1851.

" Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 60.

I could not, during the totality, in a rapid glance, perceive any light or shade on the moon's surface.

Mr. J. W. Good. KROPP, 28th July, 1851.

" Astr. Nachr.," Vol. xxxiii., p. 150.

The moon was visible during the totality, and her rim well defined,

shining with an ashy light, but I cannot say that any spot, either dark or light, was perceptible. I looked for the dark part on the upper half of the E. semi-diameter, but could not catch sight of it; the "lumière cendrée" was about as strong, not stronger than it is about the third or fourth day after new moon, when the sun is below the horizon; a very light flimsy cloud was however passing before her disc just before the totality closed, and might perhaps prevent my getting a sight of the lunar spots, although fortunately it was not opaque enough to prevent the observation of the other phenomena.

Mr. Hind. RŒVELSBERG, NEAR ENGELHOLM, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 84.

The surface of the moon was decidedly reddish purple at the beginning of totality, but the reddish tinge disappeared before its termination, and the disc assumed a dull purple colour.

The Rev. W. R. Dawes. RŒVELSBERG, NEAR ENGELHOLM, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 92.

The colour of the moon during the totality was a purplish black. No striking variations of light were observed upon its surface; but there was so much of a more imposing character to notice during the brief continuance of total darkness, that there was no time to spare for scrutinising the moon's disc.

M. Mauvais. DANTZIG, 28th July, 1851.

"Comptes Rendus," xxxiii., p. 175.

La surface de la Lune est restée d'un noir uniforme; on n'apercevait ni taches ni lumière cendrée. Moon a uniform black; no spots or ashy light perceived.

Admiral Richards.
Captain Parsons. FISGARD ISLAND, PUGET SOUND, 18th July, 1860.

MS. Reports of the 1860 Expeditions.

The disc of the moon at totality appeared of a lead-coloured hue,

brightening almost to silver near the circumference, and conveyed a vivid impression of sphericity. The sun was only $2\frac{1}{2}°$ above the horizon.

Mr. James Breen. CAMMESA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The colour of the moon was of a dark grey, and its surface was not of uniform tint; it seemed of a globular form.

Mr. J. Buckingham. CAMMESA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

Five and a half minutes before totality, the disc of the moon was clearly seen of a faint olive colour. Four seconds before totality the moon was seen as a very dark olive patch.

Mr. T. C. Janson. BURGOS, 18th July, 1860.

MS. Reports of the 1860 Expeditions.

The body of the moon appeared quite black in the centre of the corona.

Dr. J. H. von Mädler. VITORIA, 18th July, 1860.

"Über Totale Sonnenfinsternisse," p. 11. Dr. von Mädler, Jena, 1861.

The moon observed to be uniformly black—no bright spots.

Die Mondscheibe untersuchte ich gegen 30 Sekunden lang, ohne irgend eine Variation des reinen tiefen Schwarz, was über die ganze Scheibe hin gleichmässig erschien, bemerken zu können. Namentlich war nicht das mindeste von einem hellen Fleck um die Mitte herum zu bemerken. Nach Bergen des Mondrandes mich umzusehen war keine Zeit.

Frau von Mädler. VITORIA, 18th July, 1860.

"Über Totale Sonnenfinsternisse," p. 25. Dr. von Mädler, Jena, 1861.

Moon's disc a deep dark-blue, somewhat like looking into a deep hole.

Die Scheibe erschien mir tief dunkelblau und gewährte fast den Anblick als ob man in eine Vertiefung hinein schaue.

Professor Grant.

SIERRA DE TOLOÑO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

At 2 h. 52 m., [between seven and eight minutes before totality,] I carefully examined the surface of the moon and found it to exhibit a deep purple hue.

Padre Secchi.

DESIERTO DE LAS PALMAS,
18th July, 1860.

"Relazione delle Osservazioni," etc. P. Secchi, Rome, 1860.

(p. 15.) La Luna in mezzo del cielo era affatto nera e del più nero inchiostro, e per singolare illusione pareva quasi staccata dal fondo del firmamento.

The moon, inky black, appeared as if detached from the background of sky.

Mr. C. G. Walker.

MASULIPATAM,
18th Aug., 1868.

Report of the Government Astronomer upon the observations of the eclipse of 1868.

(p. 19.) The disc of the moon was intensely black, and I could not detect a speck upon it.

Professor Charles S. Pierce.
Mr. Shaler.

BARDSTOWN, KENTUCKY,
7th Aug., 1869.

"United States Coast Survey," Appendix No. 8 to Report for 1869, p. 14.

[During totality the moon] was not black, but of a deep, dull, and somewhat purplish blue, darker than the sky. Mr. SHALER confirmed this.

Mr. Warington Smyth.

ARGOS, SPAIN,
22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

The disc of the moon was black to my own and companions' view, and certainly much darker than the background of sky.

Mr. Hudson. SAN ANTONIO, SPAIN, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

I noticed that the brightness of the moon was considerably more than I expected, not so much less than before totality. I agree in the description I had seen of its "green velvety" appearance. The green was like that of the olives that were commonly on the dinner-table in that neighbourhood, but greener and less brown. The clouds drifting across the moon were perceptible, and the mountains in the moon were not.*

Capt. Tupman. SYRACUSE, 22nd Dec., 1870.

"Washington Observations," 1869, Appendix i., p. 117.

The body of the moon was considerably illuminated with a greenish grey tint, similar to the *lumière cendrée* seen at new moon. I have no doubt the irregularities of the lunar surface might have been seen. The moon was not so dark as the sky beyond the corona, of which I had an extensive view from the size of the field (which was 3° 15′ in diameter).

* In a paper, by Mr. Proctor, "On the Colour of the Moon during the late Eclipse," published in the "Monthly Notices," vol. xxxi., p. 152, he suggests that the green tinge remarked upon the moon by Mr. Hudson might be owing to the colour of the earth-shine upon its surface. He showed that at the time of the eclipse there would be a great terrestrial area covered by ocean turned towards the moon; and suggested that this might give a definite tint to the earth-light with which the lunar landscapes would be lit up; and that in looking at the tints upon the dark moon, we are in fact observing our own earth's colour seen from a distance.

If, however, all (or even any considerable part) of the light which comes to us in the direction of the dark moon were derived from the moon itself, we might expect to see the irregularities of its surface standing out as relatively brighter and darker objects, instead of the even velvety appearance which has been described by Mr. Hudson. The great maria are remarkably bad reflectors as compared with the more broken portions of the surface, and a very small degree of illumination would suffice to make them stand out as black spots upon a brighter ground. We must therefore look to the illuminated curtain of atmosphere situated between the eye of the observer and the moon as the source of by far the greater part of the light appearing to come from the moon.

CHAPTER XXX.

STARS SEEN DURING TOTALITY.

It appears that during totality the illumination of the heavens is such that only stars of the first and second magnitude are generally visible; stars of the third magnitude have been recognized, but apparently only with difficulty, by those who have previously acquainted themselves with their position.

1715.	**Halley and others.**	Jupiter, Mercury, Venus, Capella, and Aldebaran.
1842.	**Observers at Perpignan.**	4 or 5 stars.
	" beside the sea.	7 to 10.
	" at Narbonne.	4 or 5, or even 10.
	" at Montpellier.	5.
	" at Digne.	Capella, β and ζ Tauri, and γ Orionis.
1860.	**Saar.**	Jupiter, Venus, Saturn, Mercury, Castor, Pollux, Regulus, Capella, β Aurigæ, Procyon, β Canis Minoris, γ Leonis.
1868.	**Anson.**	β Leonis, Regulus.
1869.	**Schott.**	Mercury, Venus, Saturn, Arcturus, Vega, Antares, Altair, Benetnasch.
	Hill.	Venus, Mercury, Arcturus, Vega, seen. (Capella, Procyon, Castor, Pollux, Regulus, Altair, Saturn, Antares, Spica, and Mars, looked for, but not seen.)
	Perkins.	Mercury, Venus, and Saturn.

Dr. Edmund Halley. ROYAL SOCIETY'S HOUSE, CRANE COURT, LONDON, 3rd May, 1715.

"Phil. Trans." for 1715, p. 249.

The three planets, Jupiter, Mercury, and Venus, were all that were seen by the gentlemen of the Society from the top of their house, where they had a free horizon, and I do not hear that any one in town saw more than *Capella* and *Aldebaran* of the fixed stars.

M. Arago.

7th July, 1842.

"Annuaire du Bureau des Longitudes," pp. 279, 280.

At Perpignan four or five stars were seen. Beside the sea some persons seven, others ten. At Narbonne four or five, some say ten. At Montpellier, five. At Digne, four.

Les curieux qui, à Perpignan, purent donner une attention suffisante à la recherche des étoiles, en aperçurent quatre à cinq à l'œil nu. Au bord de la mer, quelques personnes en virent sept, d'autres dix. D'après les positions indiquées, il ne paraît pas que Mars ait été un des astres visibles.

MM. PINAUD et BOISGIRAUD parlent de quatre à cinq étoiles aperçues à Narbonne, pendant l'éclipse totale, vers le zénith et du côté du couchant. Divers observateurs assurèrent en avoir compté jusqu'à dix.

Les personnes de Montpellier, à qui M. l'Abbé PEYTAL demanda combien elles avaient aperçu d'étoiles, répondirent que le nombre de ces astres visibles à l'œil nu ne s'éleva pas au delà de cinq.

A Digne, M. DIEN vit à l'œil nu, la Chèvre, β et ζ du Taureau, γ d'Orion. Des vapeurs couvraient une grande partie du ciel.

Martin Saar.

VITORIA,
18th July, 1860.

"Über Totale Sonnenfinsternisse," Dr. von Mädler, Jena, 1861. (p. 12.)

Four planets seen; Jupiter five minutes before totality. Also eight stars, one of the third magnitude.

Beobachtung der mit freiem Auge während der Totalität sichtbaren Sterne durch den Diener der Sternwarte Dorpat.

Da der genannte Diener sich eines scharfen Auges erfreut und mit der gegenseitigen Stellung der Sterne nicht ganz unbekannt ist, so hielt ich ihn für geeignet diese Wahrnehmungen, zu denen andre Beobachter voraussichtlich keine Zeit haben würden, anzustellen. Zu dem Ende hatte ich eine künstliche Halbkugel, auf der die wichtigsten Sterne für den Horizont von Vitoria durchscheinend angegeben waren, vorgerichtet, in Vitoria zusammengesetzt, und sie auf einem besondern Fussgestell von 4 gegen einander geneigten Pfählen so aufgestellt, dass sie der Himmelsstellung während der totalen Finsterniss, so genau als nöthig, entsprach. Unter dieser Halbkugel befand sich M. SAAR und bezeichnete die von ihm am Himmel wahrgenommenen Sterne mit Bleistift an der innern Fläche der Halbkugel.

In dieser Weise hat er aufgefunden *Jupiter* 5 Minuten vor Eintritt der Totalität; *Venus* bald darauf; und während der Totalität *Saturn*, *Mercur*, *Castor*, *Pollux*, *Regulus*, *Capella*, *β Auriga*, *Procyon*, *β Canis Minoris*, *γ Leonis;* die sämmtlich an einer Seite des Himmels stehen und die kurze Zeit so in Anspruch nahmen, dass für eine weitere Untersuchung kein Raum bleib. *β Canis Min.* ist dritter Grösse, es hätte also wenigstens die sechsfache Anzahl wahrgenommen werden können, wenn der Himmel überall heiter gewesen wäre und man sich mit einer blossen Zählung, ohne bestimmte Bezeichnung, hatte begnügen wollen.

Lieut. Anson. MANTAWALU KIKI, CELEBES,
18th Aug., 1868.

MS. Observations of the 1868 Eclipse.

(p. 25.) At the instant of totality β Leonis, and Regulus close to the sun made their appearance simultaneously, but they both disappeared with the first glimpse of the returning bright rays. No other heavenly bodies were observed by me.

Mr. Charles A. Schott. SPRINGFIELD, ILLINOIS,
7th Aug., 1869.

"United States Coast Survey Report for 1869," Appendix No. 8, p. 50.

During totality the following heavenly bodies were seen:—Mercury, Venus, Saturn, Arcturus, Vega, Antares, Altair, and Benetnasch. Some claim to have seen more, but the above are all that were recognized by the observers. No bodies were discovered between the sun and Mercury.

President Hill. MATTOON, ILLINOIS,
27th Aug., 1869.

"Journal of the Franklin Institute," Jan., 1870, p. 67.

Venus appeared a minute or two before the total obscuration, and remained visible for several minutes after the reappearance of the sun. At the instant of total obscuration Mercury, Arcturus, and Vega appeared. Even Arcturus was of a silvery whiteness. Arcturus remained visible some seconds after the total phase had passed. We looked sharply for Capella,

Procyon, Castor and Pollux, Regulus, and Altair, and also looked less carefully for Saturn, Antares, Spica, and Mars, but we had nothing but our general recollection of the stars to guide us as to the direction in which to look, and we saw nothing either with the naked eye or our opera glasses beyond the two planets and two stars already mentioned. At the instant of total obscuration, one or two of us had a feeling that we were seeing half a dozen stars bursting into sight at once, but we could only find the two.

Mr. F. W. Perkins. BRISTOL, TENNESSEE,
7th Aug., 1869.

"United States Coast Survey Report for 1869," Appendix No. 8, p. 9.

Mercury, Venus, and Saturn were visible, but I looked in vain for stars in any of the northern constellations.

CHAPTER XXXI.

BRIGHTNESS OF THE HORIZON DURING TOTALITY.

During totality, while the heavens above the observer are comparatively dark, the sky upon the horizon appears brightly illuminated, so that mountains or buildings at a distance seem to stand up with sharply defined outlines against the sky. Thus, while objects at hand are nearly invisible, those upon the horizon are more clearly seen than they were immediately before totality. Möller and McTaggart evidently judged that the light by which they were enabled to distinguish the objects in their immediate neighbourhood, was principally derived from the clouds and sky near the horizon, rather than from direct illumination by the corona. And this becomes the more probable when we take into consideration the fact* that no shadows are cast during totality. The light from the horizon coming in all azimuths naturally casts no shadow, and it would appear that the illumination derived from this source is so great that the eye cannot distinguish between the brightness of objects so lit up, and those which are also illuminated by the light of the corona and prominences.

Dr. Axel Möller. Bezana, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

During the total eclipse the darkness was not considerable in consequence of the reflected light from the clouds which surrounded the horizon.

Mr. Joshua R. Roberts. Miranda de Ebro, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The sky was of an exceedingly dark indigo colour except around the

* For the grounds of this assertion see the chapter on the "Brightness of the Corona."

horizon, where there was a wide band of various shades of vivid red light, before which the black mountains stood out in relief.

Mr. H. M. Matthews. ORDUÑA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

There was a red light like the last tinges of a sunset in bad weather on the N.W. horizon, causing the summits of the mountains to appear sharp and strongly defined.

Mr. Thomas Pamler. A HILL NEAR ORDUÑA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

The darkness came on gradually, making objects at hand invisible, while all around the horizon the distant tops of the hills were visible, as if by a faint light from behind, and they appeared something lower than before.

Mr. C. Weiler. HILL OF SANTA MARINA, 3 MILES S.W. OF POBES,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

The outlines of the mountains were sharply defined, and in the horizon to the south, which was beset with clouds, there appeared a fire-red brightness.

Miss H. Airy. HILL ABOVE EREÑA,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

As soon as the sun was totally eclipsed, and indeed a short time before, everything changed. The distant hills came out quite a deep purple-grey colour with a distinct outline, and a most brilliant orange-coloured sky behind them, while the entire foreground was lost in a sombre dark colour.

Dr. McTaggart. SIERRA DE TOLOÑO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

[During the totality] I could distinguish the outlines of objects at a great distance, but I think that a considerable portion of the light was reflected from the distant horizon, which, aided by the light of the corona, made objects tolerably distinct.

Herr Geo. Rümker. CASTELLON DE LA PLANA, 18th July, 1860.

"Die Totale Sonnenfinsterniss am 18 Juli, 1860." 4to, Hamburg, 1861.

(p. 6.) Die Farbe der im Norden gelegenen braunen Berge verwandelte sich in Grau, während die im W. nach Villa Real hin liegenden bläulich schimmernden Berge schwarz wurden. Die Gipfel der letzteren schienen sich immer schärfer zu begränzen, ja endlich abzulösen, uns ganz nahe zu rücken. Sharp outlines of distant mountains.

CHAPTER XXXII.

DARKNESS DURING TOTALITY.

FROM the chapter on the brightness of the corona, it will be seen that but little of the light by which objects are rendered visible during totality is derived from the corona and solar appendages. And from the observations given in the last chapter it will be gathered that the light derived from the heavens is chiefly due to an illuminated belt of clouds and sky near to the horizon. As might therefore be expected the degree of darkness during totality differs greatly according to the terrestrial conditions surrounding the observer, the clearness of the atmosphere, the clouds and objects upon the horizon, the size of the area of totality, and the position of the observer within the area of darkness at the moment of his observation. Thus during the eclipse of—

1851.	**Piazzi Smyth**	Could read small print.
1860.	**James**	Could see the divisions of the thermometer, but could not see the mercury.
	Frau Mädler	Could read the thermometer as well as the finest writing.
1868.	**Tisserand**	Could easily read writing in the open air.

The following observers could only read with difficulty.

1851.	**Adams.**	Light only just sufficient to read the face of a box chronometer.
	Snow.	Not easy to decipher figures of watch.
	Miland.	Experienced difficulty in reading seconds of chronometer.

The following observers speak of the darkness as much more intense.

1851.	**Airy.**	Mr. Hasselgren could not read the minutes of the chronometer, and I could not see marks on a card without coming close to the lantern.

	Lassell.	Could not see second hand of watch.
1868.	Ragoonatha Chary.	Impossible to recognize the face of a person three yards off. Lamp-light needed for chronometer.

Observers, inside houses or so situated amongst buildings that the light from the horizon cannot reach them, have, as might be expected, had difficulty in distinguishing objects at a small distance, thus,—

1860.	Janson.	Darkness in rooms so great that we were afraid of running against furniture.
1861.	Haig.	In the town of Beejapoor, impossible to see one's own hand. At Moolwar, eye-piece dropped, and could not be found.
	Tisserand.	Inside hut of equatorial, could not read micrometer without a lamp.
1870.	Brothers.	Wife of consul could not find pieces of glass on table in dining-room.

STRUVE and AIRY, in describing the eclipse of 1860, both mention that the darkness appeared to them to be less than during the eclipses of 1842 and 1851.

At first sight the estimates of the two observers who have attempted systematically to measure the degree of darkness during totality would appear to be contradictory. According to the observation of CHEVALLIER, the general illumination during totality would appear to be much greater than that derived from a ten days moon well above the horizon. According to the observation of Mrs. EASTMAN, it would appear to be decidedly less than that of the full moon when 30° above the horizon. But it must be remembered that in the instrument used by Mrs. EASTMAN, the star was illuminated by light passing through a small aperture some ten inches above it. The aperture was covered with ground glass, but the light reaching the artificial star would nevertheless be chiefly derived from the heavens; while in the case of CHEVALLIER's observation the field on which the shadows fell was, it would seem, illuminated by light coming in all directions and consequently by direct light from the horizon. According to the observation of CHEVALLIER, the amount of illumination of the field during totality would be greater than that of a similar field illuminated by a ten days moon as 826^2 is to 193^2, or more than eighteen times greater.

With reference to the observation of the people on board the steamer near Venice in 1842,—if we assume that the smoke continued to issue from the funnel during totality we must believe that the sky at, say, some 40° or 50° above the horizon, did not form a sufficiently illuminated background to render the column of smoke visible by contrast; an observation which it seems difficult to reconcile with the fact that the illumination of the heavens during totality seems to be sufficient to blot out all stars below the third magnitude.

The following are only a few of the very numerous observations which we have collected in connection with this subject.

Dr. Edmund Halley. ROYAL SOCIETY'S HOUSE, CRANE COURT, LONDON, 22nd April, 1715.

"Phil. Trans." for 1715, p. 249.

As to the degree of darkness, it was such that one might have expected to have seen many more stars than I find were seen in London.

Mr. Jose Joaquin de Ferrer. KINDERHOOK, STATE OF NEW YORK, 16th June, 1806.

"Transactions of the American Philosophical Society," 1st Series, Vol. vi., p. 266.

The darkness was not so great as was expected, and without doubt the light was greater than that of the full moon.

Travellers near Venice. NEAR VENICE, 8th July, 1842.

"Annuaire du Bureau des Longitudes," for 1846, p. 283.

The column of smoke coming out of the chimney of a steamer near Venice was not visible to the passengers during totality, but the sparks carried up with the smoke were clearly seen.

Sur les lagunes de Venise, les voyageurs du bateau à vapeur notèrent, pendant l'éclipse totale, que la colonne de fumée sortant de la cheminée n'était plus visible. Les parcelles de chabon enflammées que la colonne entraîne toujours avec elle, semblaient ainsi isolées et produisaient un très-bel effet.

Professor Piazzi Smyth. ISLAND OF BUE,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 29.

The present darkness, however, though somewhat appalling to the senses, and sufficient to make a ship in the neighbourhood stop its course and furl its sails, was not, after all, so very intense; as not only small print could be read, but the marks of a pencil could be seen in sketching the appearances.

Professor J. C. Adams. FREDERIKSVÆRN,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 103.

The light remaining was only just sufficient to enable me to read off the face of a box chronometer which I had with me.

Mr. Robert Snow. CHRISTIANIA,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 34.

When total darkness took place, it was not easy to decipher the figures of a watch held in the hand.

The Rev. Temple Chevallier. GÖTTENBURG,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 79.

The general light of the sky [during totality] was sufficient to render the shadow cast by the taper imperceptible when the taper was 193 inches from the screen.

On the 3rd of November, 1851, when the moon was ten days old, one hour past the meridian, and shining very brightly, at $9^h\ 30^m$ p.m., I found that the same taper, in the same lantern, 152 inches from a screen, cast a shadow equal in intensity to that cast by the moon. When the taper was removed to 576 inches, the shadow was extremely faint; but, with great attention, it could be discerned until the taper was removed to 828 inches.

Sir G. B. Airy. HILL NEAR GÖTTENBURG, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 6.

A candle had been lighted in a lantern about a quarter of an hour before the totality. Mr. HASSELGREN was unable to read the minutes of the chronometer face without having the lantern held close to the chronometer. I had prepared for the occasion a circle described upon a card: I desired much to make a drawing of the prominences, at least of their positions on the limb of the moon, by marking them on this circle, but it was impossible for me to see it, and I was obliged to approach very closely to the lantern, in order to make the smallest memorandum on the card.

Mr. Lassell. TROLLHÄTTAN, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 47.

The amount of darkness may be appreciated from the fact that on withdrawing my eye from the telescope, I could neither see the seconds hand of my watch, nor the paper sufficiently to write the time down.

Mr. Miland. CHRISTIANSTADT, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 21.

During the totality, I experienced some difficulty in reading the seconds of the chronometer I held in my hand, and was glad of the assistance afforded me by the lighted candle at my feet.

Mr. T. C. Janson. BURGOS, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The darkness in the rooms was so great that we were afraid of running against the furniture in changing our places from the telescope to the balcony.

Mr. G. H. James. St. Lorenzo Mountain, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

I estimate the summit of San Lorenzo to be 6150 feet above the sea. In the west we had a view of the horizon, but elsewhere we were surrounded in clouds which shut out the surrounding country. The darkness was not so great as I had anticipated. I was able to see the divisions of the thermometers, but could not read them, being unable to observe the mercury.

M. Otto Struve. Pobes, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

I noticed also a striking difference between the eclipses I had formerly observed (1842 at Lipezk and 1851 at Lomza) and the present, with regard to the degree of darkness on the earth. Though I allowed myself only for a few seconds about the middle of totality, to turn my eye from the telescope to the surrounding country, this short inspection was sufficient to leave with me the full impression that this time the degree of darkness was considerably less than on the former occasions, and particularly than in 1842.*

Sir G. B. Airy. Hill above Hereña, 18th July, 1860.

"Monthly Notices of the R. A. S.," Vol. xxi., p. 10.

About the middle of totality I ceased for a while, in order to view the prospect with the naked eye. The general light appeared to me much greater than in the eclipses of 1842 and 1851 (one cloudy, the other hazy),

* M. Otto Struve adds that in 1842 he estimated the light during totality to be nearly equal to that of twilight at 12 o'clock on a clear night about the time of the summer solstice in the latitude of St. Petersburg. In 1860 he estimated the darkness to be equal to that of twilight at 11 o'clock at night at the same period of the year—a light by which one is able to read and write without any particular exertion of the eyes.

perhaps ten times as great; I believe that I could have read a chronometer face at the distance of twelve inches. Nevertheless it was not easy to walk where the ground was in the least uneven, and much attention to the footing was necessary.

The outlines of the mountains were clear, but all distances were totally lost; they were in fact an undivided mass of black, to within a small distance of the spectator.

Frau Mädler. VITORIA, SPAIN, 18th July, 1860.

"Über Totale Sonnenfinsternisse," Dr. von Mädler, p. 25.

I could not only easily distinguish objects during totality, but could read the finest writing and even the scale of the thermometer.

Während der totalen Finsterniss war es auf eine mich überraschende Weise hell geblieben, so dass man nicht allein deutlich jeden Gegenstand erkennen, sondern auch die feinste Schrift und selbst das Thermometer ablesen konnte.

Capt. C. T. Haig. BEEJAPOOR, 18th Aug., 1868.

"Proceedings of the Royal Society," Recess, 1868. (p. 79.)

It is very curious how the darkness during totality seems to have differed in degree in different places. At Beejapoor we were told that down below in the town the darkness was so great that it was not possible to see one's own hand. We thought this account might be an exaggeration; but we afterwards learnt that at Moolwar a gentleman dropped part of an eyepiece of a telescope, and that it was not possible to find it, even by placing the eye close to the ground, until after the end of totality.

C. Ragoonatha Chary. VUMPURTHY, 18th Aug., 1868.

Report of the Government Astronomer upon the observations of the 1868 eclipse.

(p. 25.) I can safely say that it was quite as dark as on a clear starlight night. I had to use lamp-light when looking for the time by the chronometer, and it was impossible to recognize the face of a person standing within a distance of three yards. Lighted candles appeared just as bright as in the night-time, and I was told that my lights were distinctly seen three-quarters of a mile off.

M. Tisserand. WHA-TONNE, 18th Aug., 1868.

"Rapport sur l'Observation de l'Eclipse," par M. Stephan, p. 30.

L'obscurité fut assez intense durant la totalité; en plein air, on distinguait aisément des caractères d'écriture, mais, à l'intérieur de la cabane de l'équatorial, M. TISSERAND fut obligé de prendre une lampe pour lire le tambour de son micromètre.

In the open air one could read writing, but inside the hut of the equatorial M. Tisserand was obliged o use a lamp to read his micrometer.

Mrs. Eastman. DES MOINES, IOWA, 7th Aug., 1869.

"Washington Observations" 1870, Appendix ii., p. 107.

With the photometer, [which was an instrument for measuring the amount of diffused light in the atmosphere*] Mrs. EASTMAN found the light was insufficient to render the least trace of the "star" at the base of the photometer visible. On being assured by Mr. MARRYATT that the aperture was fully open, another observation was attempted, but the "star" was not visible. A third attempt resulted in a similar failure. She then gave up the observation as hopeless.

[Prof. EASTMAN says at p. 108,] Relying on the accuracy of the statement of former observers, that the light during a total eclipse was equal to that of the full moon, the photometer was so constructed as to show the "star" with less light than that of the full moon, at an altitude of 30.° . . . [From observations made with the photometer after sunset] and from my impressions at the time of the total phase of the eclipse, I conclude that the light during the totality on Aug. 7th was about equal to that on a clear moonless evening, at the time when third-magnitude stars can be easily seen.

Mr. Brothers.
Mr. Fryer. SYRACUSE, 22nd Dec., 1870.

MS. Observations of the 1870 Eclipse.

The darkness was such that whilst a large dialled chronometer could be read in the open air the wife of the consul could not find some pieces of glass that were lying on the table of the dining-room of their house.

* For an exact description of the instrument, see the same Volume p. 100.

CHAPTER XXXIII.

UNNATURAL ILLUMINATION OF OBJECTS DURING TOTALITY.

THE red and orange light coming from the bright belt of sky and clouds upon the horizon gives to objects around the observer a peculiar and unnatural tint, which, together with the darkness above, causes a weird unearthly effect that has frequently been remarked upon. The upturned faces of the bystanders assume a sickly livid hue, which WRIGHT and PFROWNE compare to the effect produced by the light of burning salt.

Any surface of water from which the light of distant clouds can be reflected becomes, as might be expected, brilliantly lit up with reflected tints. See PIOLA, DUNKIN, and HEATH.*

M. Piola. LODI, 8th July, 1842.

"Annuaire du Bureau des Longitudes," pour 1846, p. 294.

[The colour of the sky reflected by the waters of the Po and of Lake Lecco gave them a leaden appearance which inspired terror.]

Le ciel était d'un azur violacé très-sombre. Cette dernière teinte, réflétée par les eaux du Pô et du lac de Lecco, leur donna une apparence plombée qui inspirait la terreur.

Mr. Dunkin. CHRISTIANIA, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 14.

Immediately below me was the fiord dotted with its numerous islands. Over this mixture of land and water the effect of the darkness was very peculiar, the water having the colour of a deep purple, and the islands a dusky yellow.

* R. F. Heath, observing at Peña de Castilla near Santander, says: "At the time of perfect obscuration, the colours of a belt of clouds reflecting themselves in the water were gorgeous beyond all description—I had eyes for nothing else." See MS. Reports of the Himalaya Expedition.

Prof. J. C. Adams. FREDERIKSVÆRN, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 103.

The appearance of the corona, shining with a cold, unearthly light, made an impression on my mind which can never be effaced, and an involuntary feeling of loneliness and disquietude came upon me.

Mr. E. J. Lowe. FUENTE DEL MAR, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

(pp. 22, 23.) [During totality] a white house in front just visible was yellowish in colour. . . . . The countenances of men were of a livid pink hue.

Mr. Robert Reynolds. HILL ABOVE ORDUÑA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The metallic light of which I speak, acting upon the grass and foliage, produced a sepulchral sickly tinge which made the faces of those assembled look spectral and unearthly.

Mr. John Wright. GUJULI, NEAR ORDUÑA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The light gave to the countenances of individuals a livid hue, similar to that produced by throwing salt in the flame of burning spirit.

The Rev. J. J. S. Perowne. ALI, NEAR VITORIA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

We were startled too, as we looked in one another's faces, to see the ghastly hue that had come over them. It was almost as unnatural as the effect produced by burning salt.

Prof. Grant. SIERRA DE TOLOÑO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

The aspect of their countenances strongly reminded me of the effect produced by a large fire on a dark night, only that in the present instance the complexions appeared to assume somewhat of a livid hue.

Prof. G. W. Hough. MATTOON, ILLINOIS,
7th Aug., 1869.

"The Total Eclipse of Aug. 7, 1869," by Prof. Hough, p. 19.

On the sudden extinction of the light the whole aspect of the landscape seems changed, the faces of our companions assume an ashy paleness, and all nature is surrounded with an unearthly light, producing, insensibly, a feeling of terror in the mind of the beholder.

Mr. G. W. Bean. HANOVER COLLEGE, INDIANA,
7th Aug., 1869.

"Coast Survey Report," 1869. Appendix, No. 8, p. 49.

For some time before and while totality lasted, the faces of bystanders and other light-coloured objects had a greenish-yellow colour; the leaves looked yellow.

General Abbot. MOUNT ETNA,
22nd Dec., 1870.

"Coast Survey Report" for 1870. Appendix xvi., p. 14.

At an elevation of 7,500 feet . . . the shadow swept over us—darkening the gloom to an awe-inspiring degree. The amount of light was sufficient to render ordinary type visible, but the peculiar ghastly effect was like nothing usual in nature. After continuing about a minute, this gave place suddenly to a rosy red tint which lasted fully a minute, and then gradually changed to the former inky grey.

CHAPTER XXXIV.

FLASHES OF LIGHT SEEN ON OR NEAR THE MOON'S DISC.

It will be gathered from the last three chapters that objects within the area of totality are lit up by light arriving in all azimuths from the illuminated belt of clouds and sky upon the horizon. Small bodies floating at considerable altitudes within the area of totality would, in addition to the lateral illumination, be lit up on their under sides by light derived from the surface of the earth outside the area of totality. It seems possible to conceive that such small bodies might thus appear as bright specks upon the dark background of sky. But this theory will not satisfactorily account for all the observations collected in this chapter. Murray, observing during the annular eclipse of 1851, speaks of five stationary lines across the disc of the moon.

The observers at Mattoon in 1869 speak of faint whitish bodies floating past a few moments before as well as during totality. And Weidler's friend in 1738, and Myer in 1869 describe bright bodies seen long before and long after totality. It should, however, be remembered that there are many well-known instances in which insects, thistle-seeds, and even snow-flakes have been mistaken for meteors* in ordinary sunlight.

Dr. Edmund Halley. Royal Society's House, Crane Court, London, 22nd April, 1715.

"Phil. Trans. for 1715," p. 249.

During the whole time of the total eclipse I kept my telescope con-

* See a letter from the Rev. W. Read respecting the Luminous Bodies seen on Sept. 4th, 1850, "Monthly Notices" xii., p. 38. Also a paper by the Rev. W. R. Dawes on Luminous Meteor-like Bodies, telescopically visible in Sunshine. "Monthly Notices" xii., p. 183 And a paper by Capt. John Herschel on a flight of Locusts seen in India, which he at first mistook for meteors, "Monthly Notices" xxx., p. 135.

stantly fixed on the moon, in order to observe what might occur in this uncommon appearance, and I found that there were perpetual flashes or coruscations of light, which seemed for a moment to dart out from behind the moon, now here now there, on all sides, but more especially on the western side a little before the emersion.

M. de Louville. LONDON, 3rd May, 1715.

"Mémoires de l'Académie" for 1715, pp. 126, 127.

Flashes lasting only for an instant seen upon the surface of the moon during totality.

Ce sont de certaines fulminations ou vibrations instantanées de rayons lumineux qui paroissoient sur la superficie de la lune pendant l'obscurité totale, ensorte que vous eussiez dit que l'on y aurait mis des traînées de poudre, comme quand on veut faire jouer des mines, et que l'on y auroit mis le feu. Ce spectacle imprévû causoit une espèce de frayeur aux observateurs. Je n'ai pû voir cela qu'à travers de ma lunette, mais tous ceux qui ont observé avec des lunettes l'ont remarqué. . . . Ces éclats de lumière ne duroient qu'un instant, et paroissoient tantôt dans un endroit et tantôt dans un autre, mais sur-tout du côté de l'immersion.

Herr J. F. Weidler. WURTEMBERG, 23rd Dec., 1738.

"Phil. Trans. for 1739," p. 228.

A friend of Weidler's towards the commencement of the eclipse saw lights like flashes of lightning upon the disc of the moon, and the same again after an interval of more than an hour.

Denique prætermittendum nòn duco, quod amicus, harum rerum probe gnarus qui per Telescopium Astronomicum ix. pedum solem intuebatur, circa hor. iv. 31 m. in obscuro lunæ disco lucem aliquam, instar fulguris, celeriter huc illuc in tenebris diffusam animadverterit: et quod idem observator circa horam v. min. 50 toti adstantium coronæ affirmaverit, a se tum ter talia fulgura subito enitentia iterum conspecta fuisse.

M. Arago. ESTAGEL, 8th July, 1842.

"Annuaire du Bureau des Longitudes pour 1846," p. 364.

Two luminous meteors seen to cross the sky in a direction towards the sun.

Au moment de l'éclipse totale, un de mes camarades d'enfance, M. FRANÇOIS GONSALVO, vit, à Estagel, deux météores lumineux traverser le ciel vers la région même qu'occupaient les astres en conjonction. . . .

M. Wullerstorff. VENICE, 8th July, 1842.

"Annuaire du Bureau des Longitudes pour 1846," p. 364.

La surface de la Lune, suivant M. WÜLLERSTORFF, était de temps en temps traversée par des traits lumineux. Moon's disc occasionally crossed by bright streaks.

Abbé Zantedeschi. VENICE, 8th July, 1842.

"Annuaire du Bureau des Longitudes pour 1846," p. 364.

De temps en temps, dit l'Abbé ZANTEDESCHI, on voyait (sur la Lune) de faibles éclairs intermittents, comme des jets de lumière phosphorique entremêlés de traits noirs. Feeble flashes of light visible from time to time upon the moon.

M. Piola. 8th July, 1842.

"Annuaire du Bureau des Longitudes pour 1846," p. 365.

En Italie M. PIOLA apprit de diverses personnes, qu'elles avaient vu, pendant la courte durée de l'obscurité totale, *des étoiles* filantes et un bolide. Le bolide se mouvait si près de la région occupée par la Lune, qu'il avait paru se détacher de cet astre. Shooting stars and one boloid seen during totality.

Mr. Murray. YARROWLUMLA, 31st Jan., 1851.

"Monthly Notices," Vol. xii., p. 31.

The annularity lasted exactly 3 m. The disc of the moon appeared streaked by five stationary lines; its surface appeared rough.

Prof. David Murray. MATTOON, ILLINOIS, 7th Aug., 1869.

"Journal of the Franklin Institute," Jan., 1870, p. 65.

A few moments before totality, and during that period, nearly all the telescopic observers at our station noticed faint whitish bodies, floating past their glasses. Prof. HOUGH* saw three, Mr. SWIFT four or five, Mr.

* See also Prof. Hough's pamphlet on the eclipse, p. 19; he speaks of them "as faint whitish bodies darting past the field of the telescope."

SIMONS five or six, Mr. HOUSE as many, and I saw four at least. At the time they made no impression on my mind. I thought of thistle down, or some other winged seed; others thought of midges which had been awaked by the darkness; others of swallows. But when we came to compare our observations and our conjectures, we found to our surprise that all these bodies had one direction, viz., from the north-west downwards towards the south-east, and it seemed, therefore, impossible to explain them on any of the hypotheses which had been started.

The idea that they were meteoric, is perhaps more plausible, and it is strengthened by the fact that the time nearly corresponded to the August period of meteoric showers.

Mr. Alvan G. Clark. SHELBYVILLE, 7th Aug., 1869.

"Coast Survey Report" for 1869. Appendix, No. 8, p. 23.

Mr. ALVAN G. CLARK, who observed the eclipse at Shelbyville through the finder of the Shelbyville equatorial, states . . . . that his attention was called by Professor WINLOCK to small objects crossing the field of the finder, in straight lines, and supposed by both observers to be meteors. Mr. CLARK himself observed about twenty of these objects.

Mrs. Murphy. FALMOUTH, KENTUCKY, 7th Aug., 1869.

"Coast Survey Report" for 1869. Appendix viii., p. 19.

Mrs. MURPHY saw two meteors during the total phase. The first was traced from a point near the meridian and not far from the zenith toward the south-east; the course of the second was from the north-western to the south-western part of the sky.

General Albert J. Myer. WHITE TOP MOUNTAIN, NEAR ABINGDON, VIRGINIA, 7th Aug., 1869.

"Washington Observations," 1870. Appendix ii., p. 193.

Colonel WINTHORP, my companion, described a "shower of bright specks" to which he more than once called my attention, while yet some four or five digits of the sun's disc remained uncovered, and which we do not doubt was the shower of meteors remarked upon by other observers.

CHAPTER XXXV.

WIND DURING TOTALITY.

It will be seen from the extracts collected in this chapter, that during the same eclipse very contrary atmospheric conditions have been recorded as existing during the period of totality at different stations.

Thus in 1860, nine observers describe the wind as rising, or blowing in gusts as totality came on; while Lowe, Haase, Plantamour, Rümker, and Secchi observed that the wind fell, and totality was ushered in by a comparative calm. Bruhns and Haase noticed that the wind shifted during totality; but all concur in describing a change in the atmospheric conditions which they regard as due to the approach of the totality shadow.

The only observers who mention that they looked for but failed to notice any change in the atmospheric conditions at totality are D'Abbadie in 1860, and Dudley in 1869.

1842.	**Struve.**	Lipezk.	Cool breeze during totality.
1851.	**Krag.**	Near Christiania.	Calm during totality, strong wind before and after.
	Good.	Kropp.	Wind died away to a perfect calm during totality.
	Dawes.	Rœvelsberg.	Nearly a calm.
	Humphreys.	Christianstadt.	12 m. before totality the wind almost ceased.
	Miland.	Christianstadt.	Wind ceased.
	Littrow.	Rixthöft.	Almost entirely calm.
	Feldt.	Frauenburg.	At the beginning of totality the wind shifted, it then became calm for 3 m.
1853.	**Moesta.**	Ocucaje.	Whirlwinds during totality.
1860.	**Buckingham.**	Cammesa.	Wind rose with totality.
	Lindhagen.	Bezana.	Slight wind.

	Lowe.	Fuente del Mar.	The velocity of the wind near the ground decreased at totality, but its direction remained unaltered. The direction of motion of the clouds as well as their estimated velocity also remained unaffected.
	D'Abbadie.	Breviesca.	No eclipse wind.
	Weeden.	Near Miranda.	Wind lulled about 10 minutes before totality, and blew quite freshly during totality, and soon after the passing of the shadow the wind again increased.
	Pamler.	Near Orduña.	Upper current of S. wind set in just before totality.
	Reynolds.	Near Orduña.	A few seconds before totality the clouds seemed to pause in their southward passage.
	Weiler.	Near Pobes.	Wind rose at totality, and again 2 m. after totality.
	Miss H. Airy.	Near Pobes.	Cold wind at totality.
	Perowne.	Ali.	Cold wind at totality.
	Gray.	Near Logroño.	Cold breeze at totality from N.W.
	Perry.	Near Logroño.	Strong wind suddenly arose as the eclipse approached its totality.
	Bruhns.	Tarazona.	6 m. before totality gust of wind; during totality wind shifted to N.
	Haase.	Valencia.	Strong S.E. wind lulled a few minutes before totality, gentle wind from E.N.E. during totality, and S.E. wind again after totality.
	Plantamour.	Castellon de la Plana.	Calm for half an hour towards the middle of the eclipse.
	Rümker.	Castellon de la Plana.	Sea breeze fell at totality.
	Secchi.	Desierto de las Palmas.	Calm at totality.
	Burr.	Near London.	The wind blew strongly at the time of the greatest obscuration.
1861.	Weiss.	Greece.	N. wind blowing 15 m. before totality, gust from W.S.W., calm during totality, and gust from W.S.W. after totality.
1868.	Rungacharry.	Vunpurthy.	Remarkable calm at totality.

	Pogson.	Masulipatam.	N.W. wind before totality, calm at totality, W. wind after.
1869.	**Peirce.**	Bloomington.	18 m. after totality calm, thought that the calm commenced 20 m. before totality.
	Mayer.	Burlington.	Wind sprang up at totality.
	Dudley.	Springfield.	Very slight change in force of wind noticed, none in direction.
	Blake.	Shelbyville.	28 m. before totality wind from N.E. suddenly ceased, then rose and changed to S.E.
	Dean.	Shelbyville.	Change of wind from N.E. to S.E. noticed.
	Bean.	Hanover, Indiana.	A calm at totality, but no change in direction of wind.
1870.	**Hostage.**	Cadiz.	Rush of wind at totality.
	Toynbee.	Near Cadiz.	The wind lulled during totality.
	Warington-Smyth.	Argos.	Gusts of wind at and near totality.
	Lethbridge.	Gibraltar.	Wind lulled during totality.
	Brett.	Augusta.	5 m. or 6 m. before totality wind became violent.
	Asaph Hall.	Syracuse.	Strong wind arose as totality approached.
	Harkness.	Syracuse.	Wind blowing half a gale (nothing said about increase or decrease at totality).

M. O. Struve. LIPEZK, 7th July, 1842.

"Astr. Nachr.," Vol. xx., p. 234.

Obgleich kein Wind fühlbar war, zogen doch die Wolken sehr rasch; nur während der Minuten der totalen Verfinsterung machte sich ein kühler Luftzug allen Zuschauern bemerkbar.

At Lipezk a cool breeze was felt during totality by everybody.

Lieutenant Krag. RINGERIGET, NOT FAR FROM CHRISTIANIA, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 32.

The most singular thing, however, was, that the wind, which blew hard at the early part of the eclipse, totally ceased, leaving the lake below

me smooth and calm as glass. No sooner had the shadow passed ere the wind commenced anew, with the previous force. I was not single in observing this, but several persons remarked and confirmed the same.

Mr. J. W. Good. KROPP,
28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 145.

From the very beginning of the eclipse the wind had gradually begun to die away, and during the totality a perfect calm reigned, which however as the shadow passed off gave way to a gentle breeze, which kept increasing, and at five o'clock the direction and velocity of the wind was about the same as when the eclipse began.

The Rev. W. R. Dawes. RŒVELSBERG, NEAR ENGELHOLM,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 92.

At the beginning of the eclipse there was a light breeze from the west, which gradually died away as the eclipse advanced, and about the middle of it there was nearly a calm.

Mr. Humphreys. CHRISTIANSTADT,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 18.

At about 3 h. 0 m. [twelve minutes before the commencement of totality], the wind almost ceased.

(p. 20.) At 3 h. 20 m. a light breeze sprang up from the N.W. and continued during the remainder of the day.

Mr. Miland. CHRISTIANSTADT,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 22.

Greenwich Mean Time.	Remarks.
3·10	Beginning of totality wind ceased.
3·12·45	End of totality.
3·20	Very light wind at N.W.

Dr. C. L. von Littrow. Rixthöft,
28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 134.

Der Wind war während der totalen Finsterniss beinahe völlig ausgeblieben; vor und nach diesem Zeitpunkte wehte er ziemlich heftig.

Calm during totality, afterwards moderately strong.

Dr. L. Feldt. Frauenburg,
28th July, 1851.

"Astr. Nachr.," Vol. xxxiii., p. 163.

Immediately after the beginning of totality the wind shifted to the N.W., and blew moderately hard. It then fell, and three minutes after totality it was again blowing from W.N.W.

Vor der totalen Verfinsterung.—

2 h. 49 m.* W.N.W., 2. heiter, schöner blauer Himmel.
3 h. 43 m. W.N.W., 1.2.
3 h. 53 m. W.N.W., 1.
3 h. 57 m. Wenig Wind.
4 h. 7 m. W.N.W., 1.
4 h. 17 m. W.N.W, 1.
4 h. 27 m. Fast Wind still.
4 h. 31 m. W.N.W., 0.

Gleich nach dem Eintritt der totalen Verfinsterung drehte sich der Wind nach N.W., und wurde ziemlich stark; dieser Wind hielt indessen nicht lange an, wurde bald darauf sehr schwach, und kurz vor dem Ende der totalen Verfinsterung kaum noch zu spüren. Drei Minuten nach der totalen Verfinsterung kam der Wind wieder aus W.N.W.

4 h. 42 m. W.N.W., 1. heiter, schöner blauer Himmel.
4 h. 56 m. W.N.W., 1. heiter.
5 h. 18 m. W.N.W., 2.
5 h. 28 m. W.N.W., 2. heiter.

M. Carlos Moesta. Ocucaje, Peru,
30th Nov., 1853.

"Monthly Notices," Vol. xiv., p. 231.

At the entrance of the shadow on the coast of Peru, the air, usually so hot from the sandy plain upon which it rests, suddenly condensed from the effect of the eclipse, and this caused a current of cool air to flow from the ocean for the purpose of restoring the equilibrium of the atmosphere.

* Frauenburg time.

There ought from this cause to have been a wind from the west; however, as a cool breeze from the south had continued to blow during the whole day, there was a violent meeting together of two distinct currents, and the consequence was, that during the total obscuration a succession of whirlwinds occurred, which in some instances raised the sand to a height of 200 feet.

Mr. J. Buckingham. CAMMESA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

As the shadow came on to us at totality, the wind gradually rose, putting our lights out.

Dr. D. G. Lindhagen. BEZANA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The wind continued, throughout the whole course of the eclipse, tolerably feeble and northerly; about the time of the totality stronger gusts were not observed, but I could perceive that at the time the air was in somewhat greater motion than either before or afterwards. We calculated the height of our station above the sea by barometrical measurement to be 845 metres, or about 2750 feet.

Mr. E. J. Lowe. FUENTE DEL MAR, NEAR SANTANDER, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The direction of the wind was indicated by a delicate silk flag placed 10 feet above the ground.

The velocity of the wind was indicated by a Robinson's anemometer. The numbers in the table show the number of revolutions made during the previous five minutes. Each revolution shows a velocity of 9·42 feet.

The velocity of the clouds is represented by a scale in which 0. stands for motionless, and 6 for clouds moving with great velocity.

(p. 13.) The force of the wind varied considerably, it was brisk until immediately before totality when there was a perfect calm; indeed from 2 h. 55 m. p.m. till 3 h. 5 m. p.m. the movement of the air was only 62½

yards, and this amount occurred before the commencement and after the end of totality. After totality the air did not resume the same speed, and from 3 h. 45 m. p.m. there was a dead calm.

Time.	Direction of Wind.	Velocity of Air per five minutes in number of rotations.	Direction of Cloud.	Velocity of Cloud.
1·45 p.m.	N.N.W.	470	N.W.	0½
1·50	N.N.W.	300	N.W.	0½
1·55	N.W. by N.	450	N.W.	0½
2·0	N.W.	280	N.W.	0¾
2·5	N.W.	430	N.W.	0¾
2·10	N.W.	570	N.W.	1
2·15	N.N.W.	300	N.W.	1½
2·20	N.W.	350	W.	2
2·25	N.W.	400	W.	1½
2·30	N.N.W.	470	W.N.W.	1
2·35	N.W.	150	W.N.W.	1½
2·40	N.W.	520	W.N.W.	1½
2·45	N.W.	240	W.N.W.	1½
2·50	N.W.	160	W.N.W.	1½
2·55	N.W.	270	W.N.W.	1½
* 3·0	N.W.	10	W.N.W.	...
3·5	N.W.	10	W.N.W.	1½
3·10	N.W.	70	W.N.W.	1½
3·15	N.W.	20	W.N.W.	1¼
3·20	N.W.	80	W.N.W.	1
3·25	N.W.	80	W.N.W.	1
3·30	N.W.	60	W.N.W.	0¾
3·35	N.W.	50	W.N.W.	0½
3·40	N.W.	6	W.N.W.	0½
3·45	N.W.	4	W.N.W.	0½
3·50	N.	0	N.W.	0½
3·55	N.W.	0	W.N.W.	0½
4·0	N.W.	0	W.N.W.	0½
4·5	N.W.	0	W.N.W.	0½
4·10	N.N.W.	0	W.N.W.	1

* Totality commenced just before 3 o'clock.

M. Antoine d'Abbadie. BRIVIESCA, 18th July, 1860.

"Comptes Rendus," li., p. 708.

No eclipse wind.

Les observations négatives ont aussi leur importance. . . . Le vent de l'éclipse fut nul.

Mr. F. M. Weeden. NEAR MIRANDA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

2 h. 48 m. 32 s. to 2 h. 50 m. It was about this period* that the greatest amount of quiet prevailed both in the atmosphere and in the fields, for during the actual totality the wind blew quite freshly. . . . 3 h. 8 m. The wind increased after the passing of the shadow.

Mr. Thomas Pamler. A HILL NEAR ORDUÑA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

Just before the total darkness an upper current of wind set in from the south,† which, meeting the north wind, caused the clouds to roll over like volumes of smoke. . . . Owing to the setting in of the south wind, the clouds remained nearly stationary during totality.

Mr. Robert Reynolds. NEAR ORDUÑA, 18th July, 1860.

MS. Observations of the Himalaya Expedition.

A few seconds before the totality, the clouds seemed to pause in their southward passage. This, I imagine, was owing to an upper current of wind from the south, which continued during the remainder of the eclipse.

* Totality commenced at Mr. Weeden's station at about 3 h. 0 m. 30 s. or 3 h. 1 m. 0 s.

† Mr. Weeden says that at 2 h. 30 m. (when the sun was about half covered before totality), he "noticed that an upper series of small light clouds were moving from south to north, while the lower ones kept on as before in the contrary direction, thus showing the existence of two currents of wind."

Mr. C. Weiler. HILL OF SANTA MARINA, 3 MILES S.W. OF POBES, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

With the decreasing light the wind rose, and the temperature decreased perceptibly. About two minutes after totality the wind again rose, and it became distinctly colder.

Miss H. Airy. HILL ABOVE EREÑA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

As totality came on a cold wind sprang up, and, in fact, the whole aspect of things gave me the impression of a heavy thunder-storm coming on at sunset.

The Rev. J. J. S. Perowne. ALI, NEAR VITORIA, 18th July, 1860.

MS. Observations of the Himalaya Expedition.

The atmospheric change was not less remarkable. The wind came to us cold and chilly, as from some sepulchral vault.

The Rev. C. Gray. LA GUARDIA, NEAR LOGROÑO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The breeze was remarkably cold just before and during totality. N.W. wind. Our position was on a tower in the town, and the town itself is on an isolated hill in the valley.

Mr. J. G. Perry. HILL OF CANTABRIA, NEAR LOGROÑO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The early part of the day had been calm, but as the eclipse approached its totality a strong wind suddenly arose, which during the darkness increased much in violence. When the sun's light returned the atmosphere soon subsided again into a calm, showing that the previous disturbance had arisen from the condensation occasioned by the sudden cold.

My station was upon a hill, on the left bank of the river Ebro, and elevated about 350 feet above the river.

Prof. C. Bruhns. TARAZONA, 18th July, 1860.

"Berichte der Kön. Sächs. Gesellschaft der Wissenschaften, Math. Phys. Classe, Sitzung am 12ten Dec., 1860," p. 222.

Gust of wind six minutes before totality. At first it blew from the S.W., then it shifted through W. and N.W., and during totality blew from the N.

Der Wind wehte sehr heftig, und besonders 6 Minuten vor der Totalität erhob sich ein Windstoss, der aber nur von sehr kurzer Dauer war. Der Wind, welcher anfangs aus Südwest kam, drehte sich nach und nach durch West und Nordwest und wehte während der Totalität aus Nord.*

Herr Haase. VALENCIA, 18th July, 1860.

"Astr. Nachr.," Vol. liv., p. 341.

A few minutes before the beginning of totality strong S.E. wind lulled. During totality gentle wind from E.N.E. After totality S.E. wind sprang up again, but not so strong as before.

Einige Minuten vor Beginn der Totalität legte sich der heftig blasende Südostwind ganz bedeutend, und drehte sich nach Ausweis der im Eingange beschriebenen grossen, aber anscheinend sehr beweglichen Wetterfahne nachher mit schwachem Luftzuge nach Ost-Nord-Ost. Bei der Rückbildung stellte sich zwar nach und nach die frühere Windrichtung wieder her; der Wind war aber minder stark.

Prof. Plantamour. CASTELLON DE LA PLANA, 18th July, 1860.

"Observation de l'Eclipse Totale de Soleil, du 18me Juillet, 1860," par M. le professeur E. Plantamour, Geneva, 1860, p. 12.

The sea breeze fell as the eclipse advanced; calm for half-an-hour towards the middle of the eclipse, and then increased again as before.

La brise de mer qui se fait sentir très-fortement à Castellon, a faibli à mesure que le disque du soleil était caché par celui de la lune; elle est même complètement tombée pendant une demi-heure vers le milieu de l'éclipse, et il y a eu un calme complet dans l'atmosphère; puis elle a repris avec sa régularité habituelle, lorsque le disque du soleil a été découvert en grande partie.

* See also "Astr. Nachr.," Vol. liv., p. 314.

Herr G. Rümker. CASTELLON DE LA PLANA, 18th July, 1860.

"Die Totale Sonnenfinsterniss am 18ten Juli, 1860."

(p. 14.) Es war auch nichts von einem sogenannten "Finsterniss-winde" zu verspüren, vielmehr schien sich die zu Anfang noch fühlbare leichte Seebriese nach und nach gänzlich zu legen. No eclipse-wind observed at totality, but rather the sea breeze seemed to fall.

Padre Secchi. DESIERTO DE LAS PALMAS, 18th July, 1860.

"Relazione delle Osservazioni," etc. P. Secchi, Rome, 1860.

(p. 20.) Il vento ossia la brezza marina di abbastanza forte che era prima dell' ecclisse si calmò gradatamente, e si quietò affatto nella totalità. Wind became calm during totality.

Mr. Burr. HIGHBURY, NEAR LONDON, 18th July, 1860.

"Monthly Notices," Vol. xxi., p. 25.

During the time of the greatest obscuration the wind blew strongly from the S.W. and produced an unpleasant and unusual chilliness. By 3 h. 5 m. the wind had again lowered.

Dr. Ed. Weiss. HILL ON THE LEFT BANK OF THE NEDA, MOREA, 31st Dec., 1860.

Vol. xlv. der "Sitzungsberichte der math.-naturw. Classe d. k. Akad. der Wissenschaften."

(p. 387.) Etwa eine Viertelstunde vor dem Eintritte der Totalität erhob sich ein Wind aus W.S.W., obwohl den ganzen Tag über die Luftströmung eine nördliche gewesen war, allein seine Stärke liess bald wieder nach, so dass einige Minuten vor der Totalität Windstille eintrat. . . . Wind from the N. About 15 m. before totality wind from W.S.W. 1 m. before totality, calm. 1 m. after totality gusts from W.S.W.

(p. 388.) Einige Minuten nach der Totalität wurden abermals Windstösse aus W.S.W. fühlbar, erreichten aber bei weitem nicht mehr die Stärke, welche die vor der Totalität bemerkten hatten.

Mr. C. Rungacharry. VUNPURTHY,
18th Aug., 1868.

Report of the Government Astronomer upon the observations of the 1868 Eclipse.

(p. 25.) A remarkable feature of the phenomenon was the stillness of the atmosphere during the whole time of totality, and for some time afterwards. The moderate breeze blowing at the commencement of the eclipse diminished by degrees to a dead calm, which continued for about a quarter of an hour after the sun's reappearance.

Mr. Pogson. MASULIPATAM,
18th Aug., 1868.

Report of the Government Astronomer upon the observations of the 1868 Eclipse.

(p. 12.) A light north-west wind prevailed before the eclipse, but a perfect calm for some time before and after the totality. A fresh westerly breeze sprang up with the increasing sunlight.

Mr. J. M. Peirce. BLOOMINGTON, ILLINOIS,
7th Aug., 1869.

"United States Coast Survey Report for 1869;" Appendix 8, p. 41.

At the beginning of the eclipse the wind blew freshly from the east, and was quite troublesome to us in our exposed position. But 18 m. after totality (at 12 h. 52 m.) we noticed that it had entirely died away, and we thought that this change had taken place some 20 m. before totality.

Prof. A. M. Mayer. BURLINGTON,
7th Aug., 1869.

"The Journal of the Franklin Institute," Oct., 1869, p. 259.

[At the commencement of totality] a low moaning wind sprang up, and the whole atmosphere seemed filled with a leaden-coloured vapour.

Mr. Timothy Dudley. SPRINGFIELD, ILLINOIS,
7th Aug., 1869.

"United States Coast Survey Report for 1869;" Appendix 8, p. 39.

The number 1 in the column of wind indicates a very light breeze, and 2 a gentle breeze. . . . . . The atmospheric pressure was not notably affected, and a gentle breeze at the beginning of the eclipse changed into a very light one towards its end, preserving its direction from the north-east.

Sidereal Time.	Atmospheric Pressure.	Wind. Direction and Force.	Remarks.
13 h. 00 m.	29·52	N.E. 2	
10	·52	N.E. 2	Eclipse begins.
20	·50	N.E. 2	
30	·50	N.E. 2	
40	·50	N.E. 1	
50	·50	N.E. 1	
14 00	·50	N.E. 1	
10	·50	N.E. 1	Totality.
20	·47	N.E. 1	
30	·45	N.E. 1	
40	·45	N.E. 1	
50	·45	N.E. 1	
15 00	·45	N.E. 1	
10	·45	N.E. 1	Eclipse ends.
20	·45	N.E. 1	

Mr. F. Blake, Jun. SHELBYVILLE, KENTUCKY,
7th Aug., 1869.

"United States Coast Survey Report for 1869;" Appendix No. 8, p. 29.

About twenty-eight minutes before totality the wind, which had been from the north-east, suddenly ceased. In a few minutes, however, a breeze sprang up in the south-east, and continued to blow during the remainder of the day.

Mr. Geo. W. Dean. SHELBYVILLE, KENTUCKY, 7th Aug., 1869.

"United States Coast Survey Report for 1869;" Appendix No. 8, p. 26.

I noticed the gradual falling of the temperature during the eclipse, and the sudden change of the wind from north-east to south-east.

Mr. G. W. Bean. HANOVER COLLEGE, INDIANA, 7th Aug., 1869.

"United States Coast Survey Report for 1869;" Appendix No. 8, p. 49.

Time.			Wind Strength.	Wind Direction.	Remarks.
4 h.	25 m.	45 s.	Breeze.	N.E.	First contact.
4	30	00	Light breeze.	N.E.	
4	40	00	Do.	N.E.	
4	50	00	Do.	N.E.	
5	00	00	Do.	N.E.	
5	10	00	Strong breeze.	N.E. by E.	
5	20	00	Light breeze.	N.E. by E.	
5	24	44	Calm.	...	Beginning of totality.
5	26	58	Light breeze.	N.E. by E.	End of totality.
5	30	00	Do.	N.E. by E.	
5	40	00	Do.	N.E. by E.	
5	50	00	Do.	N.E. by E.	
6	00	00	Do.	N.E. by E.	
6	20	00	Do.	N.E. by E.	
6	21	05	Do.	N.E. by E.	Last contact.

Mr. Hostage. CADIZ, SPAIN, 22nd Dec., 1860.

MS. Reports of the 1870 Expedition.

There was a sudden rush of wind at totality, and a very perceptible lowering of the temperature.

Capt. Toynbee, R.N. VINEYARD OF ST. ANTONIO, SPAIN,
22nd Dec., 1870.

At 11·49 the wind was noticed to be W. by N., blowing fresh and increasing with rain.

The wind lulled during the totality, and afterwards freshened with squalls.

Mr. Warington Smyth. ARGOS, SPAIN,
22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

The wind had changed in the night from north to south-west, bringing up large masses of cloud from the Atlantic.

Strong gusts of wind visited us, so violent, as the totality approached, that we were inconvenienced to keep our telescopes and thermometers from blowing over.

Capt. Lethbridge. H.M.S. TRAFALGAR, GIBRALTAR,
22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

The totality lasted 1 m. and 55 s., during which time the wind lulled considerably.

Wind N.W., force 3.

Mr. John Brett. AUGUSTA,
22nd Dec., 1870.

"Monthly Notices," xxxi., p. 164.

Five or six minutes before the total phase . . . . the wind, which had been strong all day, now increased considerably; some of the more violent gusts being very inconvenient in the observatory.

Prof. Asaph Hall. SYRACUSE,
22nd Dec., 1870.

"Washington Observations," for 1869, Appendix i., p. 29.

As the totality approached it became quite cold, and a strong wind arose, but as my telescope had a solid, firm mounting, the wind gave me no trouble.

Prof. Wm. Harkness.

SYRACUSE,
22nd Dec., 1870.

"Washington Observations," for 1869, Appendix i., p. 80.

A quarter of an hour before totality a dense cloud came over the sun and hid it entirely. The wind was blowing half a gale. When I tried to light my lanterns I found it was impossible, even in the most sheltered place, and I was obliged to take them into the store-house and light them there.

CHAPTER XXXVI.

DEPRESSION OF TEMPERATURE AND DEW DURING TOTALITY.

NUMEROUS observers have carefully noted the height of the barometer and the temperature as registered by wet and dry bulb thermometers during recent total and annular eclipses; but the conditions under which the various observations have been made differ in such important particulars that it has not been thought expedient, in a volume like the present, to devote the space which would be necessary for a comparison of them. The general results* which appear to have been arrived at, are that the

* The following references to some of the more important records of meteorological observations made during recent total and annular eclipses may be of service to those interested in similar investigations.

7th July, 1842.—M. O. Struve (Lipezk), "Astr. Nachr.," Vol. xx., pp. 231-4.

28th July, 1851.—Dr. L. Feldt, Observations made at Frauenburg, "Astr. Nachr.," Vol. xxxiii., p. 164; M. E. Renou (Vendôme), "Comptes Rendus," Vol. xxxiii., p. 160; Dr. Julius Schmidt (Rastenburg), "Beobachtung der totalen Sonnenfinsterniss," Schmidt, pp. 22, 23; Dr. Schubart (Storlus), "Bericht von Herr A. von Parpart," p. 20, and M. Sire (Besançon) "Comptes Rendus," xxxiii., p. 158.

26th May, 1854 (Annular Eclipse).—Prof. Stephen Alexander and Mr. Gibson (Ogdensburgh, N. Y.), Gould's "Astronomical Journal," Vol. iv., p. 21; Prof. Bartlett (West Point), Gould's "Astr. Journal," Vol. iv., p. 35.

14th March, 1858 (Annular Eclipse).—See the eighteenth vol. of the "Monthly Notices" for accounts of meteorological observations made by Mr. J. G. Barclay at Leyton, Prof. Challis at Cambridge, Mr. James Glaisher at Oundle, Mr. Simmons in London, Prof. Piazzi Smyth in Edinburgh, and Mr. C. H. Weston at Bath.

7th Sept., 1858.—For observations by M. Liais, M. Martini, M. Pouillet, M. Senna Pereira, see "Astr. Nachr.," Vol. xlix., pp. 296—299.

18th July, 1860.—Sig. Botella (Desierto de las Palmas), "Über totale Sonnenfinsternisse," by Mädler, pp. 28, 29; Mr. J. R. Clare (York Factory, Hudson's Bay), MS. Report in the possession of the R. A. S. In the MS. Reports of the Himalaya Expedition, see observations by the Rev. C. Gray (Logroño), Mr. H. Greenbank (Orduña), Captain Jacob (Sierra de Toloño), Mr. G. H. James (San Lorenzo), Dr. Lindelöf (Bezaña), Dr. Lindhagen (Bezaña), Mr. E. J. Lowe, and others (Fuente del Mar). This is a very important report. All the appliances for a meteo-

height of the barometer is not materially affected by the passage of the shadow, but that there is a marked depression of temperature as the time of totality approaches, which varies in amount according to local circumstances, the season of the year, and the height of the sun above the horizon at the time of central eclipse. In illustration of the difference of the range of temperature due to local causes, see a table given by E. J. LOWE, in the MS. observations of the Himalaya Expedition, in which are tabulated the ranges of temperature indicated by black-bulb thermometers placed on the grass at nine different places within the limits of the shadow path. At Los Corrales the range of temperature indicated was only 17·5 degrees, while at Quintinellia the range was 66·3 degrees.

Observers frequently mention that they were conscious of a sensation of chilliness at the time of totality, but DE FERRER, ARAGO, LITTROW, SCHMIDT, VAN PELT, RAPATEL, and HILL are, as far as we are aware, the only observers who mention that dew was actually deposited during the period of central eclipse.

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rological station were taken to Spain, and thirty-five different series of observations as to the state of the clouds, the velocity and direction of the wind, temperature, ozone, etc., etc., were taken at intervals of five minutes during the eclipse. See also Dr. McTaggart's "Actinometer Measures" (Sierra de Toloño), Mr. H. M. Mathews (Orduña), Sig. Mantesino (Bilbao), Mr. Murrey (Llodio), and the Professors of the Biscayan Institute (Bilboa). See also accounts of observations by Herr Rümker at Castellon de la Plana, printed in Rümker's "Totale Sonnenfinsternisse," 1860, p. 14; by P. A. Secchi, at Desierto de las Palmas, printed in "Relazione della Osservazione Secchi," p. 42; and Prof. C. Bruhns (Tarazona), in the "Bericht der Kön. Sachs. Gesellschaft," for Dec., 1860. Dr. James Brown (Steilacoon), "Coast Survey Report" for 1860, Appendix 22, p. 17.

18th Aug., 1868.—Mr. C. Appoo Iyengar (Vunpurthy), "Report of the Government Astronomer," p. 26; Herr C. Koppe (Mulwar), "Vierteljahrsschrift," vii. Jahrgang, 3ten Heft, pp. 218—222; Mr. N. R. Pogson (Masulipatam), "Report of the Government Astronomer," p. 12; Lieut. T. R. Ross (Matawalu Kiki), "MS. Reports of the 1868 Eclipse," p. 30.

7th Aug., 1869.—Prof. Eastman (Des Moines, Iowa), a very complete series of actinometer and meteorological observations printed at length in the "Coast Survey Reports for 1869," appendix ii., pp. 99—120; Mr. J. C. House (Mattoon), given in Prof. Hough's Report, p. 32; Prof. E. C. Pickering (Mt. Pleasant, Iowa), "Journal of the Franklin Institute," for Oct., 1869; and Prof. T. H. Smith (Mattoon), Prof. Hough's Report, pp. 32, 33, Mr. G. W. Bean (Hanover College, Indiana), "Coast Survey Report for 1869, appendix viii., p. 49.

22nd Dec., 1870.—Capt. Lethbridge (Gibraltar), Prof. Silvestri (Etna), and Capt. Toynbee (San Antonio), all in the MS. Reports of the 1870 Expedition.

Mr. Jose Joaquin de Ferrer. KINDERHOOK, STATE OF NEW YORK, 16th June, 1806.

"Transactions of the American Philosophical Society," 1st Series, Vol. vi., p. 267.

A little dew fell during the darkness.

M. Arago. PERPIGNAN, 8th July, 1842.

"Annuaire du Bureau des Longitudes pour 1846," p. 288.

A la campagne, près de Perpignan, il y eut, après l'obscurité totale, une forte rosée. Elle tombait des feuilles par grouttelettes.

Near to Perpignan there was heavy dew after totality, which fell from the leaves in drops.

D. C. L. von Littrow. VIENNA, 7th July, 1842.

"Annalen der k. k. Sternwarte in Wien, Neuer Folge," II. Band, p. xlvi.

Die Abkühlung hatte bedeutenden zweiten Thau und eine Nebelbildung zur Folge, die entschieden der Finsterniss angehörte, da sie mit ihr gleichen Schritt ging.

The cooling wa the cause of dew and a fog, which undoubtedly belonged to the eclipse, because they disappeared with it.

Dr. Julius Schmidt. RASTENBURG, 23rd July, 1851.

"Beobachtung der totalen Sonnenfinsterniss," Schmidt, Bonn, 1852.

(p. 23.) Der Thaufall während der Totalität ist ein unzweifelhaftes Factum, wobei indessen nicht zu übersehen, dass er stellenweis wegen localer Modificationen ausbleiben kann. Bei uns beschlug er die Spiegel des Polariscops so sehr, dass darüber die letzte Betrachtung des Farbenbildes verloren ging, und es wäre den Beobachtern künftiger totaler Finsternisse wohl anzuempfehlen, sich für alle Fälle mit einer Röhre zum Schutze des Objectivglases an ihrem Fernrohre zu versehen. Jeder, der von den Feldern vor Rastenburg in die Stadt zurückkehrte, sprach von dem Thau, den er an den Steinen, am Grase, oder am Gebüsch auf dem Rasen entlang gehend, an seiner Kleidung und an den Füssen bemerkt hatte.

That there was dew during totality is an undoubted fact. The last observation with the polariscope was lost by reason of the dew upon the reflector. Everybody returning from the fields about Rastenburg spoke of the dew upon the stones, the grass, and the bushes.

Dr. van Pelt. WILLIAMSVILLE, N. Y., 26th May, 1854.

"Gould's Astronomical Journal," Vol. iii., No. 72.

[Annular eclipse.] The afternoon of the 26th was without a cloud. The leaves on the trees were without motion by the wind until the beginning of the eclipse, when a very gentle cool breeze from the west could be felt during the whole time . . . There was a slight formation of dew.

M. Rapatel. ON BOARD THE LABOURDONNAIS, BETWEEN MADRAS AND CALCUTTA, 18th Aug., 1868.

"Comptes Rendus," lxvii., p. 802.

Before totality there was a marked fall in the temperature, and in consequence there was abundance of dew.

Il y a eu, bien avant que l'éclipse fût totale, un changement de température marqué, et tout le monde ressentit une fraicheur très-prononcée; il en résulta une rosée abondante sur la lisse du bord.

President Hill. MATTOON, ILLINOIS, 27th Aug., 1869.

"Journal of the Franklin Institute," Jan., 1870, p. 67.

Some of us thought there was a slight deposit of dew upon the grass, but others failed to perceive it.

CHAPTER XXXVII.

EFFECT OF ECLIPSE ON MEN, ANIMALS, AND PLANTS.

We only give a selection from the very numerous observations which have been made on this subject. There seems to be but little difference of opinion as to the effect produced by an eclipse upon the vegetable kingdom. Flowers and leaves which ordinarily close at night begin long before totality to show signs of closing up. Kutczycki and Ross agree that in the insect world ants go on working during totality, while Secchi concurs with Ross as to the fact that grasshoppers are stilled by the darkness. Admiral Smyth mentions that earth-worms came to the surface of the ground during an eclipse that was far from total. Higher up in the scale of life the effects seem to vary with the particular temperament of the animals observed; thus the fowls described by Lentheric sought shelter, and Kutczycki's fowls crouched, while the chickens mentioned by Murray scratched away as if nothing were happening.

Admiral Smyth.

Bedford,
15th May, 1836.

"Cycle of Celestial Objects," Vol. i., p. 143.

The crocus, gentian, and anemone partially closed their flowers, and reopened them as the phenomenon passed off: and a delicate South African mimosa, which we had reared from a seed, entirely folded its pinnate leaves until the sun was uncovered. More than one person took notice, that while the temperature was at its lowest scale, the earth-worms crept from their holes.*

* When the eclipse was at its greatest, a segment of the sun remained, equal in breadth to about one-fourth of the solar diameter.

M. Arago. 8th July, 1842.

"Annuaire, pour 1846, du Bureau des Longitudes."

M. de C. gave a piece of bread to a dog which had been made to fast since the night before. It commenced eating it, but ceased as totality began. M. Lenthéric says that bats and owls came out at totality and the swallows disappeared.

(p. 308.) M. de C——, de Perpignan, priva, à dessein, son chien de nourriture, à partir de la soirée du 7 juillet. Le lendemain matin, au moment où l'eclipse totale *allait* avoir lieu, M. de C—— jeta un morceau de pain au pauvre animal, qui commençait à le dévorer, lorsque les derniers rayons du soleil disparurent. Aussitôt le chien laissa tomber le pain; il ne le reprit qu'au bout de deux minutes, après la fin de l'obscurité totale, et le mangea alors avec une grande avidité.

(p. 312.) M. Lenthéric, professeur à Montpellier, a donné aussi quelques détails concernant les effets que l'éclipse totale produisit sur diverses espèces d'animaux.

Des chauves-souris, croyant la nuit venue, quittèrent leurs retraites; un hibou, sorti d'une tour de Saint-Pierre, traversa, en volant, la place du Peyrou; les hirondelles disparurent, les poules rentrèrent.

M. Kutczycki. Honolulu, 7th Aug., 1850.

"Comptes Rendus," xxxii., p. 637.

Fowls crouched down where they were. But a train of ants went on working as if nothing had happened.

Les poules, les premières, se sont couchées, non en allant à leurs perchoirs ordinaires, mais en s'accroupissant où elles se trouvaient . . . .

Une seule exception que j'ai remarquée, c'est que les fourmis, dont une traînée travaillait tranquillement sur le mur à côté de moi, n'ont été nullement influencées par l'éclipse; elles continuaient paisiblement leur ouvrage. C'étaient de toutes petites fourmis remplissant les maisons dans tous les pays entre-tropicaux, et qui, généralement habituées à travailler la nuit, n'ont fait aucune attention au changement survenu pendant l'éclipse.

Prof. Liveing. Frederiksværn, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 106.

A crow was the only animal near me; it seemed quite bewildered, croaking and flying backwards and forwards near the ground in an uncertain manner.

Mr. L. Svangren. LILLA EDET,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 67.

The night violet, which shortly before the beginning of the eclipse had little of its agreeable scent about it, smelt strongly during the totality.

The Rev. W. R. Dawes. RÆVELSBERG, NEAR ENGELHOLM,
28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 93.

The only effect which I observed on the animal creation was exhibited by a calf, which was feeding near us. Immediately on the disappearance of the sun it began to low most piteously, and continued to do so till the sun reappeared, when it quietly returned to its grazing.

Lieut. J. M. Gilliss. NEAR OLMOS, PERU,
7th Sept., 1858.

"Monthly Notices," xx., p. 301.

Two citizens of Olmos stood within a few feet of me, watching in silence, and with anxious countenances, the rapid and fearful decrease of light. They were wholly ignorant that any sudden effect would follow the total obscuration of the sun. At that instant, one exclaimed in terror "La Gloria," and both I believe fell to their knees filled with awe. They appreciated the resemblance of the corona to the halos with which the old masters have encircled their ideals of the heads of our Saviour and the Madonna, and devoutly regarded this as a manifestation of the Divine presence.

M. d'Essalles.

18th July, 1860.

"Astr. Nachr.," Vol. liv., p. 79.

Pendant l'éclipse presque totale qui a eu lieu dans le département de l'Hérault,* les feuilles de trois acasias de Constantinople, qui se ferment pendant l'obscurité de la nuit et nullement quand les nuages obscurissent

Eclipse not total, but the leaves of three acacias which usually close during the night were partly closed.

* More than a hundred miles away from the path of totality.

le soleil, se sont en partie fermées, mais sur quelques rameaux seulement, aucun rapport n'existant sur les trois sujets entre la quantité de feuilles fermées et la quotité de l'éclipse.

Padre A. Secchi. DESIERTO DE LAS PALMAS, 18th July, 1860.

"Comptes Rendus," li., p. 162.

The animals in our neighbourhood made no movement which showed that they were affected. Only the grasshoppers were quiet, and we saw a bat flying.

Les animaux qui se trouvaient aux environs ne firent aucun mouvement qui indiquât qu'ils fussent affectés; seulement les cigales se turent, et nous vîmes une chauve-souris voltiger près de l'ermitage.

Mahmoud Bey. DONGOLAH, 18th July, 1860.

"Comptes Rendus," Vol. li., p. 684.

At the instant of totality all became silent. The two minutes of the eclipse seemed like two hours. Many persons whom I questioned said that it had lasted two hours.

Mais, à l'instant même de l'obscurité complète, tout devint silencieux et muet. Plus un cri, plus un bruissement, plus même un souffle, mais partout l'anxiété et la consternation. Les deux minutes de l'éclipse furent pour tous deux heures.

Je n'exagère et n'imagine rien dans ces détails. Plusieurs personnes que j'interrogeai après l'éclipse sur la durée de l'obscurité totale me répondirent qu'elle avait durée deux heures. Nous n'avons pu nous-même, tant cet effet est irrésistible, nous défendre d'une profonde émotion.

Mr. T. R. J. Ross. MATAWALU KIKI, CELEBES, 18th Aug., 1868.

MS. Observations of the 1868 Eclipse.

(p. 4.) A cow, some domestic fowls, two geese, a dog, a cat, and a grey parrot were landed [from H. M. S. Serpent, for the purpose of observing the effect of the eclipse on animals].

(p. 31.) A small cock which had beforehand been actively employed grubbing about in the sand, went to sleep with his head under his wing and slept for about ten minutes, and on waking uttered an expression of surprise but did not crow. Another cock a little distance off, which did not go to sleep during the darkness, crowed on the return of light.

A number of pigeons went to roost in a tree for about ten minutes, having gathered there previously during the increasing darkness one by one; they left together in a flock shortly after the light returned.

I observed a moth flying about when it was dark.

Most small insects appeared to rest, and the chirping of the crickets was hushed, although the ants (which were very numerous and of various sorts) appeared to be as active as ever.

Prof. David Murray. MATTOON, ILLINOIS, 7th. Aug., 1869.

"The Total Eclipse of Aug. 7th, 1869," 8vo, Albany, 1870.

(p. 20.) People instinctively shouted when the first beam of light appeared.

An unruly cow, accustomed to jump into a cornfield at night, was found there after the eclipse.

During the most exciting period of the eclipse, General KEIFER saw a man going at full speed across the street, who said he was going to see what his chickens were doing. He soon returned in a state of intense disgust, declaring, in a very emphatic manner, that they were scratching away as if nothing had happened.

CHAPTER XXXVIII.

MAGNETIC OBSERVATIONS DURING ECLIPSES.

It has repeatedly been suggested that the interposition of a body such as that of the moon in the magnetic field between the earth and sun, might possibly give rise to a temporary change of appreciable magnitude in the direction of the earth's magnetic axis. But the evidence in favour of such disturbance during eclipses is not strong.

Secchi, Whipple, and Perry state that there is no evidence of disturbance due to the eclipses of 1860, 1870, and 1871, and it should be remembered that Whipple and Perry have had the advantage of being able to compare at their leisure the photographic records of delicate instruments.

Lion in 1851 thought that he detected during the time of the eclipse an increase in magnetic intensity, but in 1871 he found no disturbance perceptible with his instruments. The earth-currents observed by Triger, Grard and Laisement were intermittent and do not appear to have increased in intensity with the progress of the eclipse. The state of the evidence for and against the existence of an appreciable disturbance in the magnetic elements during eclipses may be gathered from the following table.

1851.	**Lion.**	Increase of magnetic intensity during eclipse.
1854.	**Kirkwood.**	N. pole of magnetic needle moved westward during the eclipse about 45′.
1860.	**Secchi.**	No evidence of disturbance.
1870.	**Cultrera.** **Bonifacio.**	Minimum of declination about time of totality.
	Muller. **Serra.**	Decided influence observed.
	Whipple.	No influence detected.
1871.	**Bergsma.**	No considerable influence detected.
	Lion.	Influence not detected.

Triger. **Grard.** **Laisement.**	Intermittent earth currents observed at Alençon.
Perry.	No influence detected at Stonyhurst observatory.

Prof. Lion.

BEAUME,
28th July, 1851.

"Comptes Rendus," xxxiii., p. 203.

Une demi-heure avant l'immersion, je disposai, sur l'appui de la fenêtre d'un pavillon dans un jardin, une boussole de déclinaison directement éclairée du soleil. Une montre à secondes était placée non loin, et toutes les précautions nécessaires furent prises pour éviter les influences accidentelles.

Declination magnet brought round through 60 degrees by means of a steel point, and the number of oscillations per minute observed before, during, and after eclipse. 32 oscillations observed before and after eclipse; 33 oscillations during eclipse. Number of oscillations per minute found not to vary with temperature.

Quand tout fut prêt, je déviai de 60 degrés, à l'aide d'une pointe d'acier, l'extrémité nord de l'aiguille, puis, à un battement de seconde, je l'abandonnai et je comptai les oscillations durant une minute : elles furent au nombre de *trente-deux*. A partir de ce moment, l'expérience fut recommencée alternativement par l'un des assistants, M. MOREAU, et par moi, *six fois* avant que l'éclipse eût commencée, *sept fois* pendant la durée de l'éclipse, et *six fois* après que l'éclipse eût cessé. Un intervalle de deux à cinq minutes séparait les observations consécutives. Voici les résultats : Avant l'éclipse, six observations; trente-deux oscillations par minute, sans variation saisissable. Pendant l'éclipse, sept observations :—

Rang des Observations.	Phases de l'Eclipse.	Nombre des Oscillations par minute.
Première observation	Premier quart	32·0
Deuxième observation	Deuxième quart	32·5
Troisième observation		32·5
Quatrième observation	Troisième quart	33·0
Cinquième observation		33·0
Sixième observation	Quatrième quart	32·5
Septième observation		32·0

Après l'éclipse, six observations; trente-deux oscillations par minute, sans variation saisissable.

Le lendemain et le surlendemain, le nombre des oscillations obtenues soit à la même heure, soit une heure plus tard, fut encore toujours de trente-deux par minute.

D'après cet ensemble d'observations, pendant l'éclipse, le nombre des oscillations s'est régulièrement accru, annonçant une augmentation de tension magnétique, tandis qu'à tout autre moment le nombre des oscillations resta constant . . . Je crois devoir compléter cette communication par celle d'observations faites pour vérifier si cette augmentation pouvait être attribuée à l'abaissement de la température locale pendant l'éclipse.

Pour cette vérification, j'ai refait l'expérience dans le même lieu d'observation avec les mêmes instruments, d'abord à 2 heures après-midi, *sous une forte insolation de la boussole, par* 32 *degrés Réaumur au soleil* (20 degrés à l'ombre), puis de 11 heures du soir à minuit, par 16 degrés Réaumur. Eh bien, dans l'un et l'autre cas, malgré une différence de température de 14 degrés Réaumur, le nombre des oscillations n'a pas sensiblement varié, il a toujours été de trente-deux par minute.

Prof. Daniel Kirkwood. DELAWARE COLLEGE (?), 26th May, 1854.

Gould's "Astronomical Journal," Vol. iii., No. 72.

The north pole of the magnetic needle moved westwards during the eclipse about 45′*. To-day the same needle, during the same time, has remained stationary.

Padre A. Secchi. DESIERTO DE LAS PALMAS, 18th July, 1860.

"Comptes Rendus," li., p. 161, and 279.

A declinometer observed at intervals every five minutes, during totality showed no disturbance.

(p. 161.) Un déclinomètre de JONES très-sensible observé d'heure en heure par M. MAYO, ingénieur, ne donne aucune marque de dérangement . . . .

(p. 279.) Je vous disais dans l'autre lettre que le déclinomètre a été observé chaque heure: cela n'est pas exact; les observations ont été

* Prof. Stephen Alexander says (at p. 29 of Gould's "Astronomical Journal," Vol. iv.) that on the evening of the 26th of May there was a display of the aurora borealis which was especially conspicuous.

faites de 15 en 15 minutes avant l'éclipse, et de 5 en 5 minutes près de la totalité et durant la totalité même; et sa marche, sensiblement la même qu'à l'ordinaire, montre la fausseté de certaines théories relatives à ce sujet, émises autrefois.

Padre Cultrera.
Capt. Bonifacio.

AUGUSTA,
22nd Dec., 1876.

"Rapporti dalla Commissione Italiana," p. 93.

Padre CULTRERA and Capt. BONIFACIO made magnetic observations at intervals of five minutes during the eclipse. A description of the instruments used is given by Padre SECCHI on p. 25. A table of their observations is given on p. 93, and a curve corresponding to the table is given on plate vi. Padre DENZA in describing the observations on p. 87 says: Il minimo di declinazione avvenne intorno all' ora della totalità, mentre il massimo ebbe luogo circa mezz' ora prima che incominciasse l'Eclisse, contro ciò che suole avvenire a quest' ora. Il medio spostamento diurno non fu esagerato, e la deviazione dell' ago nella sera fu pressochè uguale a quella del mattino . . . .

The minimum of declination took place about the time of totality, whilst the maximum was about half an hour before the commencement of the eclipse.

La giornata del 22, sotto l' aspetto meteorologico, fu del tutto anormale, e che nell' ora dell' Eclisse noi ci trovavamo in piena burrasca, cioè sul lembo estremo del centro della depressione, che in quel momento altraversava le nostre contrade.

Sig. Diamilla Muller.
Capitano Serra.

TERRANOVA,
22nd Dec., 1870.

"Rapporti dalla Commissione Italiana," pp. 177 to 189.

Sig. MULLER and Capt. SERRA believe that their observations show that the eclipse had a marked influence on the magnetic conditions at Terranova, and on comparing their observations with the magnetic registers made at fixed observatories situated outside the path of totality—they conclude that the influence produced by the eclipse was less as the stations were more distant from the path of totality.

Mr. G. M. Whipple. KEW OBSERVATORY, 22nd Dec., 1870.

"Nature," Vol v., p. 285.

Shortly after the eclipse of 1870 Signor DIAMILLA MULLER of Florence published a paper in the *Gazzetta Ufficiale*, No. 17, describing some magnetic observations made in Italy during the 21st, 22nd, and 23rd December, from which it appeared that there was a slight variation in the curve of the 22nd at the time of the eclipse, which did not appear in the curves of the preceding and subsequent days. Signor MULLER at once concluded that the variation was produced by the eclipse; but it was pointed out by Senhor CAPELLO, of the Lisbon Observatory, that the same disturbance was recorded by his self-recording instruments, but it occurred some time before the totality. It was also recorded by the instruments here, and proved to be insignificant when compared with other disturbances continually observed.

A careful examination of the curves for the time of the 1860 eclipse has also failed to show any trace of a similar movement then occurring.

Mr. Bergsma. BATAVIA, JAVA, 12th Dec., 1871.

Letter from Prof. Oudemans on the observations of the eclipse in Java. "Nature," Vol. vi., p. 160.

See also "Comptes Rendus," lxxiv., p. 1468.

Mr. BERGSMA caused observations of the declination of the magnet to be made during the whole morning, several days before, the day of, and several days after, the eclipse, at intervals of five minutes.

The observations are now reduced for the influence of the moon, and he will propose to the [Dutch] Government to publish these observations and their reduction apart. The result of the observations is, that the movements of the magnet-needle during the eclipse have not deviated considerably from the common diurnal movement of the declination at this time of the year.

Prof. Lion.
M. Triger.
M. Grard.
M. Laisement.

ALENÇON,
12th Dec., 1871.

" Comptes Rendus," lxxiv., p. 199 (extrait par M. Le Verrier).

M. LION, professeur à Alençon, a le premier signalé l'influence possible des éclipses de soleil sur les éléments du magnétisme terrestre. L'honorable professeur fait connaître qu'il a observé à Alençon, pendant l'éclipse totale du 11 décembre dernier. L'insuffisance de la boussole dont il se servait ne lui a permis d'observer aucune sorte de variations.

M. Lion of Alençon found no perceptible disturbance.

Il paraît en avoir été autrement au Bureau télégraphique, où M. TRIGER, inspecteur, et MM. GRARD et LAISEMENT ont cherché à reconnaître si pendant l'éclipse, des courants électriques traverseraient les conducteurs télégraphiques préalablement mis en communication avec la Terre à leurs deux extrémités. Ces Messieurs croient pouvoir affirmer qu'il en a été ainsi.

MM. Triger, Grard, and Laisement found indications of very considerable earth currents at the times indicated in the text.

Un galvanomètre à aiguilles astatiques, détaché d'un appareil de Mellòni, appartenant au lycée, ayant été introduit dans le circuit télégraphique, il éprouva les perturbations suivantes. De 2 h. 3 m. à 2 h. 7 m. du matin, oscillations très-prononcées, variant entre zéro et 10 degrés à l'ouest.

De 3 h. 0 m. 5 s. à 3 h. 2 m. 15 s. mouvement d'oscillation s'étendant jusqu'à 8 degrés à l'ouest.

De 4 h. 5 m. à 4 h. 6 m, légères oscillations s'étendant à 2 degrés à l'ouest.

De 4 h. 30 m. à 4 h. 31 m., nouvelles légères oscillations s'étendant à 2 degrés à l'ouest.

De 3 h. 54 m. à 3 h. 55 m., écart de 1 degré à l'ouest.

De 6 h. 4 m. à 6 h. 5 m., oscillations s'étendant jusqu'à 30 degrés à l'ouest.

De 6 h. 9 m. à 6 h. 12 m., oscillations s'étendant jusqu'à 5 degrés à l'ouest.

En dehors de ces intervalles de temps, on ne remarqua ni agitation ni déviation de la boussole.

Rev. S. J. Perry. STONYHURST OBSERVATORY,
12th Dec., 1871.

"Nature," Vol. v., p. 269.

In the list of papers read before the Paris Academy of Sciences, which was given in last week's "Nature," I noticed one on the magnetic perturbations observed at Alençon during the late total eclipse. Now it would at first sight appear reasonable to expect that any effect produced on the magnetic needle at Alençon by a phenomenon whose maximum phase was as far removed as India or Australia, should have nearly equal effect on the needle in England, and in all countries adjoining France. It has moreover been established by frequent comparisons of carefully measured photographic records, taken at different magnetic observatories, that any disturbance of the earth's magnetic force is felt almost simultaneously at stations differing several hundred miles in both latitude and longitude. I was therefore justified in supposing that I should find some indications on our photo-magnetic records of a disturbance corresponding to the perturbations of the needle at Alençon, alluded to by M. LION in his note to the Academy. The result of my examination of the records is, that there is not the slightest trace of a disturbance on either the vertical or horizontal curves, and that the declination magnet has been more than usually quiet, although on the two previous days it happened to have been somewhat disturbed about the hour at which the totality of Dec. 12th occurred.

Accidental causes influence too largely the readings of a declination magnet for much reliance to be placed on them, however careful the observer, when they are in open contradiction to the photo-records of instruments whose diurnal corrections are sensibly constant.

CHAPTER XXXIX.

TROU D'ULLOA AND NOTCHES SEEN IN THE LIMB OF THE MOON.

THE indentations or notches beneath prominences spoken of by so many observers, are, it can hardly be doubted, due to irradiation which causes the brilliant prominences to seem larger than they really are and consequently to appear to overlap the limb of the dark moon. In order to account for SHORT's observation it has been suggested that by "within the limb of the moon" he meant *along* the limb measured from the point of the solar cusp. The spot of light "of irregular figure" may, if such be his meaning, have been a prominence seen through the illuminated atmosphere. But it is also possible that it may have been a ghost formed by reflection from the lenses within the telescope, in which case there is no difficulty in supposing that it may have been seen projected upon the body of the dark moon.

As to ULLOA's account there can be little doubt, now that it is examined by the light of modern observations, that "the red luminous point" seen by him and his companions "near the edge of the moon" was a prominence, the summit of which was slowly uncovered by the western limb. But the observation has constantly been referred to as if ULLOA had seen a bright spot *upon* the disc of the moon. It will however be noticed that he does not describe the spot as within the limb, but speaks of it as "so near to the edge of the moon that it left no doubt of its belonging to the sun." * The name 'trou d'Ulloa' has come to be recognized as meaning

* On p. 115 of the "Phil. Trans." for 1779, Ulloa says, "The time elapsed between the first appearance of the sun's body through the aperture of the limb of the moon will serve to determine the depth of the said chink, aperture, or inequality." In the French account it is called "fente, ouverture, ou inégalité."

a hole, seen apparently through the disc of the moon during an eclipse. But no such hole or even spot of light has, as far as we can gather (if we disregard the doubtful observation of SHORT and the curious supposed evidence of the Ottumwa photograph), ever been observed.

The notches in the moon's limb under the prominences which are clearly to be seen in all the corona photographs, or at least in all of them in which the corona has any considerable extension, may be easily explained as due to an enlargement or spreading of the images of the prominences known as photographic irradiation. A similar spreading is to be found in all over-exposed photographs of luminous objects. It has been shown to be caused* partly by the optical imperfections of the instrument with which the photograph is taken, and partly by the action of light reflected from the back of the plate. The notches caused by photographic irradiation under the prominences are well shown in the steel plates from Lord LINDSAY's and Col. TENNANT's corona photographs, given at the end of the present volume.

In the plate from Mr. BROTHERS's Syracuse photograph, another phenomenon connected with notches under the prominences is depicted. The telescope has, it would appear, vibrated or shifted during the exposure, and all the prominences are seen lengthened out into short parallel bands which encroach upon the disc of the dark moon. The reason of this obviously is that the light from the prominences is so intense that they are depicted almost instantaneously upon the photographic plate. A similar phenomenon, except that the prominences are shown as doubled, is to be seen on one of Mr. DE LA RUE's 1860 photographs, and also on one of Commander ASHE's 1869 photographs.

In one of the Ottumwa photographs there is a bright patch distinctly within the moon's limb, immediately under the great prominence; this, however, may be readily accounted for as being due to reflection of the light of the prominence from the concave surface of a drop of water adhering to the back of the photographic plate during the exposure.

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* See *Monthly Notices*, xxxii., pp. 313—317, and Nature, vol. x., pp. 85, 205, 223, 245, and 522. See also a paper by Capt. Abney in the "Phil. Mag.," vol. L. p. 46.

Mr. James Short. ABERDOUR CASTLE, SCOTLAND, 14th July, 1748.

Hutton's "Abridgment of the Phil. Trans.," Vol. xi., pp. 593-4.

Mr. SHORT observed, also, about the middle of the eclipse, a remarkable large spot of light, of an irregular figure, and of considerable brightness, about 7′ or 8′ within the limb of the moon next the western cusp. He thought he lost this light several times; but whether this was owing to shutting his eyes, in order to relieve them, or not, he cannot tell. He was told that the Rev. Mr. IRWIN at Elgin observed the same. When Mr. SHORT first perceived it, he called to Lord MORTON, who was in the next room, but he could not see it.

Don Ulloa. OBSERVED AT SEA, 24th June, 1778.

"Phil. Trans.," Part i. for 1779.

(p. 110.) Before the edge of the sun's disc emerged from that of the moon, there was discovered near that of the latter a very small point of that of the sun; it was imperceptible to the naked eye, but having looked at it with the glass I estimated it at first to be about the magnitude of a star of the fourth order; after which it seemed to increase to that of one of the third. Its first appearance, to wit, that before the edge of the sun emerged from that of the moon, lasted about a minute and a quarter; the luminous circle was still visible, though already much weaker than it had been . . .

(p. 113.) The point of the sun's disc, which was seen before its limb began to emerge from that of the moon, is a very extraordinary phenomenon which I was not acquainted with before. In order to obviate all doubts which might arise about it, I must mention that we were three observers, Don JOACHIN D'ARANDA, Lieutenant WINTUYSEN, and I. Mr. D'ARANDA, who was looking at the eclipse through a two-foot telescope about the end of the total obscurity, was the first who perceived it. He, not knowing what it was, told me that the total obscurity drew near an end, because he discovered a small point of the sun, like a star, on the edge of the moon. I looked immediately with the naked eye, but saw nothing. I then took out a spyglass, with which I saw as much. At length I took out my telescope of two feet and a half, and did discover with

that a red luminous point, so near the edge of the moon that it left me no doubts of its belonging to the body of the sun. I at that time estimated it to be about the size of a star of the third magnitude; and imagine, that when Mr. D'ARANDA discovered it, it must have been like one of the fourth. This point gradually increased, and when it became of the bigness of a star of the second magnitude, the edge of the sun emerged from that of the moon. The interval between the first discovery of this point and the beginning of the emersion, was about a minute and a quarter. This apparition of the sun, before the beginning of the emersion, can only have taken place through some crevice or inequality on the limb of the moon.

M. Benj. Valz. MARSEILLES, 8th July, 1842.

"Astr. Nachr.," Vol. xx., p. 12.

40 seconds before the reappearance of the sun two brilliant points seen upon the moon's limb, with rays diverging from them. Like Ulloa, I had the impression that I was really looking at a point of the sun's disc.

40 s. avant la réapparition du soleil, et près du bord où je l'attendois, je vis paroître deux points rapprochés très-brillans, plus même que des étoiles de 1e grandeur, d'une lumière pareille à celle du soleil, et de chacun desquels on voyait surgie un rayon divergent presque de la longueur du diamètre de la lune, semblables à ceux introduits dans une chambre obscure, et concourant à former une portion de gloire des saints. J'eus aussitôt, comme ULLOA, la conviction, que je voyais bien un point même du disque solaire.

Prof. Bayma. NOVARRE, 8th July, 1842.

"Comptes Rendus," xxxiii., p. 15.

Two luminous cones seen near to the limb of the moon entering on the disc like notches.

En 1842, à Novarre, pendant l'éclipse totale, il [Prof. BAYMA] avait employé un télescope de 80 millimètres d'ouverture construit par FRAUNHOFER, et, après avoir ôté le verre noir, à l'instant de l'obscurité totale, il vit deux cônes lumineux tout près du bord de la lune, mais rentrant dans le disque comme des entailles.

Mr. Francis Baily. PAVIA, 8th July, 1842.

"Monthly Notices," Vol. v., p. 213.

During the time of total obscuration, I examined carefully with the

telescope the body of the moon, but could not discern any bright spot that might be mistaken for a hole; nor could I discover any coruscations issuing from the dark side of the moon. There, however, were only momentary observations.

Dr. Stubendorff. KORÄKOF, 7th July, 1842.

"Astr. Nachr.," Vol. xx., p. 182.

11 Uhr 41 Minuten 32 Secunden brach der erste Sonnenstrahl wieder hervor. Ehe dieser aber geschah, bemerkte man am rechten Mondsrande im obern Drittheil 2 glänzend weisse Einschnitte, wie von äusserst reinem aber mattgeschliffenem Silber, ohne alles Colorit, das dauerte ungefähr 8—10 Secunden.

8 to 10 seconds before the end of totality two shining silver-white notches seen in the moon's limb.

Mr. Lassell. TROLLHÄLTEN, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 48.

The moon appeared to my unassisted eye to be not very round or smooth at its edge—more as if one had rudely cut out with a knife on a board a circular disc of card—the edges somewhat jagged and irregular in outline.

Mr. J. W. Good. KROPP, 28th July, 1851.

"Astr. Nachr,." Vol. xxxiii., p. 150.

Neither the hole seen by ULLOA in the eclipse of 1778, nor those stated by VALZ in Marseilles and STUBENDORFF as visible in 1842 were observable.

Lieut. Thos. L. Casey. FORT STEILACOOM, 18th July, 1860.

"Coast Survey Report, 1860," Appendix No. 22, p. 16.

At several places I noticed bright yellow flame-like coruscations, as though streaming through indentations in the edge of the moon's disc.

Herr G. von Rennenkampff. VITORIA, 18th July, 1860.

"Über Totale Sonnenfinsternisse," Dr. von Mädler, p. 18.

A faint light on the disc of the moon observed near to the place where the sun disappeared. It stretched over a sixth part of its diameter.

An der Stelle, wo die Sonne verschwunden war, glaubte ich einen schwachen Lichtschimmer auf der Scheibe des Mondes zu bemerken, der sich bis zum 6ten Theile derselben erstreckte.

Herr G. Rümker. CASTELLON DE LA PLANA, 18th July, 1860.

"Die Totale Sonnenfinsterniss am 18ten Juli, 1860." 4to, Hamburg, 1860.

No extension of prominences on to the limb of the moon.

(p. 9.) Das Licht der Hervorragungen war keineswegs durch den weissen Lichtsaum der Corona umschleiert; auch muss ich noch bemerken dass keine derselben, wie frühere Beobachter gesehen zu haben glauben, sich rückwärts auf den Mondrand zu verlängern schien.

Padre Secchi. DESIERTO DE LAS PALMAS, 18th July, 1860.

"Relazione della Osservazione" . . . . P. Secchi, Rome, 1860.

No spots or active volcanoes or coruscations of light seen upon the moon.

(p. 19.) Nè furono viste da nostri le macchie o i vulcani accesi, nè alcuna corruscazione luminosa su la Luna.

M. Rapatel. ON BOARD THE LABOURDONNAIS, BETWEEN MADRAS AND CALCUTTA, 18th Aug., 1868.

"Comptes Rendus," lxvii., p. 801.

Some officers say that one of the protuberances encroached on the black circle of the moon.

Quelques officiers prétendent qu'une des protubérances empiétait sur le cercle noir de la Lune, ce que je n'ai pas constaté par moi-meme.

Commander Ashe. JEFFERSON CITY, IOWA, 7th Aug., 1869.

"The Proceedings of the Canadian Eclipse Party, 1869."

(p. 16.) Nothing was more conspicuous than the indentations of the glowing masses upon the limb of the moon. . . . Directly after the eclipse a carpenter touched me on the arm, and said, "But what were the notches on the moon?" The word "notches" was his own, and no other word do I think so applicable.

Mr. J. M. Peirce. SPRINGFIELD, ILLINOIS, 7th Aug., 1869.

"United States Coast Survey Report for 1869," Appendix 8, p. 41.

The moon had not to my eye the spherical look which is ascribed to it in some accounts of total eclipses. It resembled rather a black, jagged wafer, a portentous blot in the midst of the brightness of the corona.

Prof. David Murray. MATTOON, ILLINOIS, 7th Aug., 1869.

"The Total Eclipse of Aug. 7th, 1869," by Prof. G. W. Hough.

(p. 17.) The position of the great protuberance was 20° to the apparent north of the equator. Its base was estimated at three times its height. Directly under it was seen a white spot, nearly as large as the protuberance itself. This was probably its reflection on the disc of the moon.

Mr. Lewis Swift. MATTOON, ILLINOIS, 7th Aug., 1869.

"The Total Eclipse of Aug. 7th, 1869," by Prof. G. W. Hough.

(p. 26.) Directly under the large protuberance was a strong light visible on the moon, extending downwards as far as the protuberance did upwards, and was seen by the naked eye as plainly as the protuberance itself. After the total phase of the eclipse was over, the first question asked by the hundreds of visitors was, "What is the cause of the notch in the moon?" they thinking the light was a part of the sun seen through an open space in the moon.

Mr. Charles I. Allen. BRISTOL, TENNESSEE, 7th Aug., 1869.

"Coast Survey Report for 1869," Appendix No. 8, p. 9.

Of the rose-coloured protuberances, the most distinct was directly opposite the vertex; it continued throughout the period of totality, and was visible to the naked eye. A faint light of a rose colour, in the shape of a cone, extended from it towards the centre of the moon's disc.

CHAPTER XL.

ZODIACAL LIGHT AND INTRA-MERCURIAL PLANETS SEARCHED FOR DURING TOTALITY.

When the amount of atmospheric illumination during totality is remembered, it will probably not be thought remarkable that the zodiacal light should have been looked for without success by Goldschmidt, Rapatel, and Newcomb, during the eclipses of 1860, 1868, and 1869. Secchi, by the "piogge di meteore" which he failed to observe in 1860, probably refers to the same phenomenon.

Intra-Mercurial planets have also been carefully searched for during totality, but without success, by Secchi, Newcomb, Gould, and Schott. There can be little doubt that the point of light seen by Gilman's party at St. Paul's Junction, Iowa, was the star π Cancri. At the time of totality it was situated* at a distance of about 51′ from the sun's limb and at a position angle of 228° from the north point. In the British Association Catalogue π Cancri is given as of the sixth magnitude. The

* At 11 h. G.M.T. on the 7th of August, 1869, the position of the sun's centre would be R.A. 9 h. 11 m. 25·10 s., and N.P.D. 73° 46′ 5·4″, sun's semidiameter 15′ 48·7″. The position of π Cancri given in the B.A.C. is R.A. 9 h. 6 m. 56·63s., N.P.D. 74° 26′ 20·9″; hence the apparent place on August 7th, 1869, would be R.A. 9 h. 7 m. 59·53s., N.P.D. 74° 31′ 1·3″, which gives a distance of 66·9′ from the sun's centre, or 51·1′ from the limb, and a position angle of 227° 46′. It is strange that neither Newcomb nor Gould detected π^1 Cancri, which is nearly of the same magnitude with π Cancri, and is situated rather more than half a degree to the west of it. Any planet such as Lescarbault's would, unless very near to inferior conjunction, certainly have been more conspicuous than a star of the fifth magnitude. It may, however, be urged that the planet might have been hidden by the sun near to its superior conjunction. But as it was observed by Lescarbault on the 26th of March, it could only be hidden by the sun, or be seen projected upon it, when the earth was near to its line of nodes towards the end of March or the end of September. Gould's observation was made early in August. Lescarbault estimated that the black spot seen by him upon the sun had a diameter of rather less than a quarter of that of Mercury as seen in transit.

observers describe the star as one-tenth or one-sixth the size of Mercury, and estimate its position angle as at about 230° from the north point. GOULD estimates its distance from the sun's limb as scarcely 50′.

Herr Hermann Goldschmidt. VITORIA, 18th July, 1860.

Astr. Nachr.," * Vol. lvi., p. 308.

Ich habe keine Spur des Zodiakallichtes sehen können. No trace of zodiacal light seen.

Padre Secchi. DESIERTO DE LAS PALMAS, 18th July, 1860.

"Relazione della Osservazione," etc. . . . P. Secchi, Rome, 1860.

(p. 19.) Fu cercato del novello preteso pianeta di LESCARBAULT senza successo, nè furono viste da nostri le piogge di meteore sul corpo solare aspettate secondo alcune teorie. The little planet of Lescarbault was searched for without success, nor was the rain of meteors upon the body of the sun observed.

M. Rapatel. ON BOARD THE LABOURDONNAIS, BETWEEN MADRAS AND CALCUTTA, 18th Aug., 1868.

"Comptes Rendus," lxvii., p. 801.

J'ai inutilement cherché à voir des traces de lumière zodiacale. I searched in vain to see any traces of the zodiacal light.

Mr. W. S. Gilman, Jun. ST. PAUL'S JUNCTION, PLYMOUTH COUNTY, IOWA, 7th Aug., 1869.

"Washington Observations, 1867," Appendix ii., p. 180.

A few moments after the formation of the corona, a minute object was noted independently by four of the party, and should be here mentioned.

A small but exceedingly bright point, like a star, was witnessed by Messrs. FARRELL, PHELPS, and LOCKLIN, and Mrs. FARRELL during the period of totality. It appeared near the limits of the corona, below the

* See also "Comptes Rendus," li., p. 268.

moon's disc—direct vision—and in the region of the anvil-shaped protuberance. Mr. FARRELL judged it to be about one-sixth—some say one-tenth—the size of Mercury; which latter star was almost directly to the right of it, on a line parallel to the horizon.

With the exception of Mrs. FARRELL, all located the star a little to the right of the red prominence, or at about 230° from the north point, reckoning by the east. Each of the observers mentioned feels very positive that what he saw was truly a star.*

Prof. Simon Newcomb.

DES MOINES,
7th Aug., 1869.

"Washington Observations," 1867, Appendix ii., pp. 7—9.

(p. 8.) The main object I kept in view was to determine whether there was anything at all visible outside the usually assigned limits of the corona, and yet so near the sun as to be invisible at other times. More especially was it determined to search in the neighbourhood of the sun for an immense group of very minute intra-Mercurial planets, the existence of which had been rendered so probable by the researches of LE VERRIER on the motion of Mercury. In making this search my plan was to set two of the telescopes, the 3 inch and 4 inch, in known directions, by pointing each of them on the sun at some definite moment, ten or fifteen minutes before the commencement of totality, and immediately after the latter phase to make a map of any objects that might be seen in either field of view; then to move the telescope into different positions and count the objects in each field of view.

* On p. 176 of the same report, Mr. Gilman mentions that about half a minute before totality Mr. Vincent exclaimed that he saw a miniature crescent-shaped star under the moon. Mr. Gilman hurriedly looked for it with his telescope, but detected nothing in the few seconds he gave to the search. According to a drawing made by Mr. Vincent, soon after the eclipse, "the little moon was located one and a half times the moon's diameter from its limb, and to the left of a line drawn perpendicularly down to the horizon." Mr. Gilman thinks that he did not search the sky as far away from the moon as the distance indicated in the sketch. During the totality the object was forgotten, but shortly after the third contact, Mr. Vincent readily picked it up in the same locality. No attempt seems to have been made to determine whether the small crescent moved relatively to the sun when the telescope was moved; nor is anything said as to the position of the horns of the crescent, relatively to the horns of the solar crescent, as seen before and after totality. The position of the small crescent does not correspond with that of either Mercury or Venus at the time of the eclipse.

After thus setting the telescopes, and removing the caps and coloured glasses, I got into a nearly dark box, requesting President FRAZIER to call when he saw the sunlight was just about to disappear.

(p. 7.) [Before totality I had arranged] three circular screens of 15, 18, and 21 inches diameter, in such a position that they would just hide the sun from points near the south end of my observatory during the total eclipse. Their diameters as measured with a sextant from the observatory were respectively 33′, 39′, and 46′, the largest one being furthest out . . .

(p. 9.) I emerged from the box a few seconds before total darkness, but did not look up until Professor FRAZIER had given me the word. I then took a single glance at the corona through two thicknesses of green glass. I then attempted to hide the corona behind the outer and the larger of the screens, and thought I had done so, but after the total phase had passed I was convinced that I had mistaken the moon itself for the screen. Though I knew theoretically that the sky in the direction of the moon ought to seem darker than that outside of the corona, I was wholly unprepared for so strong an illusion of a black globe hanging in mid air. The corona itself was less bright than I had anticipated. I then looked most carefully along the direction of the ecliptic to ascertain whether there was any appearance of a blush of light extending out in that direction, but I could not perceive the faintest trace of any.

I next went in succession to the two telescopes, but not an object was visible in either. I then swept somewhat at random, but near the ecliptic, with the comet-seeker, without finding anything. As any isolated object I might find would not only be incapable of certain identification, but would fail to fulfil the condition of accounting for the motion of the perihelion of Mercury, I could only regard further search as useless, and therefore proceeded to study the corona.

Prof. B. A. Gould. IOWA, 7th Aug., 1869.

"Astr. Nachr.," Vol. lxxiv., p. 376.

My own attention was given (after noting the contacts) to a study of the corona and a search for any possible inferior planet. I had an equatorially mounted comet-seeker with a clear aperture of 5 inches, and a power of only 5. This gave great intensity of light and a field of more

than 1° 45′ in diameter. With it I succeeded in detecting π Leonis * (magn. 5·8) although scarcely 50′ from the sun's limb, but there was certainly no other star as bright as magn. 5 within 25′ of the ecliptic for 2° on either side of the sun, or as bright as the 6th magnitude an equal distance beyond these two degrees.

Mr. Charles A. Schott. SPRINGFIELD, ILLINOIS, 7th Aug., 1869.

"Coast Survey Report," for 1869. Appendix No. 8, p. 50.

During the totality the following heavenly bodies were seen . . .

No bodies were discovered between the sun and Mercury.

* Professor Gould probably means π Cancri. With a power of 5 the greater part of the light from his 5 inch object-glass would be lost. That entering his eye would be derived from an area of his object-glass of five times the diameter of his pupil as expanded during totality. With such a pencil stars of the 7th magnitude would no doubt be easily visible if the illumination of the atmosphere permitted stars of the 3rd magnitude to be seen with the naked eye.

CHAPTER XLI.

BRIGHTNESS OF THE CORONA.

THE following observers state that they were unable to detect any shadow cast by the corona :—1715, HALLEY ; 1842, JAUBERT, PINAUD, BOISGIRAUD, BELLI, FEDOROW ; 1851, friend of ADAMS, friend of CHEVALLIER, SWAN ; 1858, AZAMBUJA ; 1860, LESPIAULT, BURAT, CUILLIER ; 1868, RAPATEL. Amongst these JAUBERT describes the special precautions which he adopted in order more completely to satisfy himself that no shadow could be detected. PINAUD, BOISGIRAUD, BELLI, the friend of CHEVALLIER, SWAN, and CUILLIER, all mention that they had intended specially to devote themselves to measuring the amount of light given by the corona, and it may no doubt, therefore, be assumed that they carefully endeavoured to detect a shadow. On the other hand, LARGETEAU, observing in 1852, relates that he perceived a very faint, but still a distinct, shadow cast by his finger. SERGIANT, in 1851, speaks of shadows whose borders were pretty well defined, and whose limits were parallel amongst themselves, as if he referred to several shadows cast from distant points. CHEVALLIER, in 1860, describes the corona as casting a shadow from a pencil in writing. But none of these latter three observers mention any precautions which they took to satisfy themselves that the shadows observed were really cast by the corona.

Several observers have attempted to compare the light of the corona with that given by the full moon. HALLEY estimated that the light of the corona seen in 1715 was "vastly inferior to that of the full moon." BELLI, in 1842, who was short-sighted, compared the brightness of the confused patch of light which the corona presented to him with that produced by a candle at a distance of 1·80 metres, and he thus estimated that the light of the corona was 6·59 times greater than that of the full moon observed at a nearly similar altitude. BILLERBECK, in 1851, considered that the light

of the corona, as seen in the polariscope, was not nearly as bright as that of the full moon observed in the same instrument; but he estimated that it was about as bright as that from the moon at its first or last quarter. WILSON, during the eclipse of 1860, found that the prominences and lower parts of the corona were visible through the thickest parts of a wedge of dark glass which extinguished the light from the full moon at about its middle part. CURTIS, in 1869, found that he could not see the image of the corona thrown by his finder upon a screen, although he had previously tested and found that the image of the moon could be seen with perfect distinctness when similarly projected on the screen. It would thus appear that the total illuminating power of the corona is considerably less than that of the full moon, though the prominences and lower parts of the corona—or at all events of the corona of 1860—were brighter, area for area, than the full moon.

BECK's observation in 1860 would also appear to show that the corona, or at least parts of the corona, were brighter, area for area, than the flame of a candle. It should, however, be noticed that BECK is not careful to explain whether it was through the blue or the white part of the flame that the corona was seen, or, as he puts it, whether it was the blue or white part of the flame which the light of the corona obliterated; but he mentions that there was a strong wind blowing which would no doubt greatly increase the blue area of the flame. LIAIS, in 1858, estimated by means of a polarizing photometer that the light of the corona was twenty-five times as brilliant as the light derived from the place of the dark moon during totality.

The dazzling brightness of the corona has been remarked upon by BIELA, STRUVE, and RANYARD; but the eye when dazzled would not be able to distinguish between the parts of the corona from which the brilliant light is derived, and the whole corona would thus be spoken of as dazzlingly bright, when no doubt the chief source of illumination was from the prominences and coronal area immediately adjacent to the moon's limb.

As to observers who have made experiments relative to the brightness of the coronal image projected upon screens, CHEVALLIER, in 1860, found that the corona was visible when projected, by a telescope $3\frac{1}{2}$ inches in diameter, on to a screen so that the image of the sun was six inches in

diameter. CURTIS, in 1869, was unable to see the image of the corona thrown by his finder. He does not mention the diameter of the image, but the diameter of his finder was 1·7 inches. On the other hand, YOUNG, in 1869, found that the image of the corona in the principal focus of his telescope of six inches aperture and about eight feet focus was abundantly bright to enable him to place the slit upon any desired portion of the corona with perfect certainty.

As to the heat derived from the solar appendages during totality, MAGRINI, by an experiment, the details of which are not sufficiently described in the "Annalen der Wiener Sternwarte," or in the "Annuaire du Bureau des Longitudes," found that the heat derived from the corona was very considerable compared with that derived from the full moon.

MACLEAR, in 1871, found that he was "unable to detect any spectrum" from "any part of the corona" with a direct-vision spectroscope with which he had previously plainly seen three lines in the spectrum of the nebula in the sword handle of Orion. There seems to be some little doubt as to the breadth of the slit on the two occasions, but we may probably safely infer that the monochromatic light emitted by any area of the brilliant corona of Dec., 1871, was, (since there is but one striking coronal line,) less than one-third of the monochromatic light emitted by an equal area of the nebula of Orion. No doubt, however, the greater part of the light from the corona is made up of continuous spectrum, which is entirely lost sight of in the above comparison.

Dr. Edmund Halley. ROYAL SOCIETY'S HOUSE, CRANE COURT, LONDON, 22nd April, 1715.

"Phil. Trans. for 1715," p. 249.

Nor was the light of the ring round the moon capable of effacing the lustre of the stars, for it was vastly inferior to that of the full moon, and so weak that I did not observe that it cast a shade.

M. Jaubert. PERPIGNAN, 8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 344.

J'avais placé un feuillet de papier blanc sur le parapet de la terrasse, No shadow observable on a

schwarzen Mond. Als ich aber ans Fernrohr kam, sah ich, dass die Sonne gänzlich fehlte, und der schwarze Mond von einem hellen Schein umgeben war.

Prof. Fedorow. TSCHERNIGOW, 7th July, 1842.

"Astr. Nachr.," Vol. xx., p. 238.

Although the ring was so bright about the dark moon, Fedorow could not observe any sort of sharply defined shadows of objects.

So schön glänzend der Ring um den dunkeln Mond herum war, so konnte ich doch nichts von einigermassen scharf begränzten Schatten der Gegenstände bemerken.

M. O. Struve. LIPEZK, 7th July, 1842.

"Astr. Nachr.," Vol. xx., p. 229.

Corona so bright that the undefended eye could with difficulty bear to look at it.

Sein Glanz war dabei so blendend, dass das unbewaffnete Auge ihn nur mit Mühe ertrug.

A friend of Prof. Adams. FREDERIKSVERN, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., Pt. i., p. 107.

The corona cast no shadow.

A friend of the Rev. Temple Chevallier. GÖTTENBURG, 28th July, 1851.

"Memoirs of the R. A. S.," Vol xxi., Pt. i., p. 79.

In order to form some judgment of the degree of light during the total obscuration, I requested a gentleman present to endeavour to find at what distance from a screen a wax taper in a lantern should be held, so that any shadow thrown by the corona should be equal in intensity to the shadow thrown by the taper. The corona cast no shadow; but the general light of the sky was sufficient to render the shadow cast by the taper imperceptible when the taper was 193 inches from the screen.

Mr. Wm. Swan. A HILL NEAR GÖTTENBURG, 28th July, 1851.

"Transactions of the Royal Society of Edinburgh," Vol. xx., Pt. iii., p. 343.

I wished to compare the shadow cast by the corona with that formed by a candle; but upon a rapid trial it was found that the corona cast no sensible shadow—its feeble light being evidently overpowered by the diffuse illumination derived from the horizon.

M. Sergiant. DANTZIG, 28th July, 1851.

"Comptes Rendus," Vol. xxxiii., p. 177.

Pendant l'éclipse totale, je fis mouvoir un crayon au dessus d'un papier blanc, et je remarquai que les ombres* étaient assez bien terminées; leur limites étaient parallèles entre elles.

During the eclipse I moved a pencil over some white paper, and remarked that the shadows were tolerably sharp,

Herr A. Billerbeck. RASTENBURG, 28th July, 1851.

"Beobachtung der totalen Sonnenfinsterniss," Schmidt, 1852, p. 18.

Erwägt man hierbei noch die Bemerkung von BILLERBECK, dass die Bilder des Rastenburger Polariscops im Lichte des Vollmondes betrachtet, an Deutlichkeit und Farbenreichthum bei weitem die Bilder während der Totalfinsterniss übertroffen haben, so folgt jedenfalls, dass die Corona *nicht* die Intensität des Vollmondes hatte, auch wenn man abrechnet, was der während der Totalität fallende Thau dem Polariscopbilde an Klarheit und Farbe rauben mochten. BILLERBECK meinte nach seinen Beobachtungen, dass die Lichtmenge der Corona etwa der des ersten oder letzten Mondviertels gleich komme.

The light of the full moon as seen in the Rastenburg polariscope appeared much brighter than that of the corona. After taking into account the amount of dew on the polariscope during totality, Herr Billerbeck thought that the light of the corona was about equal to that of the moon at its first or last quarter,

M. Liais.
M. Azambuja. PARANAGUA, 7th Sept., 1858.

"Astr. Nachr.," Vol xlix., pp. 288-9.

Deux observations ont été faites sur l'intensité de la lumière de la

Azambuja remarked that no shadows were cast by the corona.

* It would seem that more than one shadow was cast; there is nothing to show that any one of them was from the corona.

M. Liais observed with a small telescope, in the focus of which was a rectangular diaphragm. The light from the corona and disc of the moon passing through the diaphragm were examined by means of a tourmaline and double image prism. The tourmaline was then turned till the light of the corona as seen in one image of the slit, appeared equal to the light from the moon as seen in the other. M. Liais thus calculated that the light of the corona was 25 times as intense as the light from the place of the moon's disc.

couronne. La première par M. D'AZAMBUJA, qui a remarqué qu'elle ne produisait pas d'ombres; la seconde par M. LIAIS, qui a employé un photomètre qu'il avait imaginé dans ce but, et qui se composait d'une petite lunette à champ étroit et rectangulaire, qui était placée sur la même monture que les autres lunettes du même observateur et parallèlement à elles, de sorte qu'elle était déjà pointée sur la lune quand il a commencé l'observation. L'image de ce champ était doublée par un prisme biréfringent, et une tourmaline tournait devant ce prisme. M. LIAIS amena rapidement la tourmaline à une position telle que dans la fente de gauche, la portion de cette fente qui se projetait sur la couronne, lui parût de même intensité que la portion de l'autre image de la fente dans laquelle se projetait le centre de la lune. Il laissa ensuite la tourmaline dans cette position, remettant la lecture après le retour du soleil, et il passa à d'autres observations. Plus tard la position donnée à la tourmaline a été examinée, et il a été reconnu que son axe faisait un angle de 2° 15′ avec la section principale du prisme biréfringent. Le rapport de l'intensité de la lumière atmosphérique dans la région de la lune, plus la lumière cendrée à la lumière de la couronne est donc égale à la tangente de 2° 15′ ou à 0,039. En d'autres termes, la couronne, et il s'agit ici de la région la plus brillante vers le milieu de la totalité et non pas de la partie la plus intense, c'est-à-dire à l'E. de la lune au commencement du phénomène et à l'O. à la fin, est environ 25 fois plus lumineuse que l'atmosphère dans la région de la lune, plus la lumière cendrée. Or l'intensité de la lumière atmosphérique, étant mesurée par la visibilité des étoiles, cela complète la mesure photométrique ci-dessus.

M. Lespiault. BRIVIESCA,
M. Burat. 18th July, 1860.

"Observations sur l'Eclipse Totale du 18 Juillet, 1860," par MM. Lespiault et Burat.

The corona cast no perceptible shadow.

(p. 9.) La couronne lumineuse ne projetait pas d'ombre sensible.

Prof. Chevallier. PANCERBO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

The corona was visible projected upon a darkened screen attached to

the eye-tube of a telescope of $3\frac{1}{2}$ inches aperture and 3 ft. 6 in. focal length. The screen was so fixed that the image of the sun was about six inches in diameter.

The light of the corona cast a shadow from a pencil in writing. My impression is that the light of the corona and of the sky was two or three times greater than at the total eclipse observed in Sweden in 1851. The greater altitude of the sun, and the much clearer atmosphere of Spain, together with the difference of elevation of the stations, may account for some difference; but a considerable portion must, I think, be ascribed to an absolutely greater intensity of light.

Mr. J. M. Wilson. PANCERBO,
18th July, 1860.

MS. Reports of the Himalaya Expedition.

To estimate the intensity of the light of the corona, I took up a wedge of coloured glass fitted so as to move easily in a frame, with a screen to show through what exact part of the wedge an object was visible . . . . But the corona was so brilliant as to disappoint our hopes of obtaining an exact measure of its intensity. As I slid the dark glass before the eye, the corona was diminished in size gradually—the brightest parts being nearest to the sun; but seen through the thickest parts of the wedge, the corona was seen as a bright ring broken in one place, and having protuberances in two parts, which correspond exactly with the long wavy extensions of the corona which were visible both in the telescope and to the naked eye.

On the evening of the 20th of July I examined the light of the new moon with the same glass. The evening being perfectly clear, it was visible through the thinnest part with ease, and gradually fading away, was lost (to my eye at least) at about the middle part of the wedge.*

* In an article on the eclipse in the second volume of the *Eagle* (a magazine published by the members of St. John's College, Cambridge), at p. 184, Mr. Wilson says that "the brightness of the corona was nearly equivalent to that of a light cirrocumulus cloud about 12° or 15° below the sun ten minutes after its reappearance, but somewhat exceeded it in brightness. It was also not very unequal in intensity to the flame of a wax candle at ten feet distance.

Mr. W. Beck. MIRANDA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The corona was of a dazzling white—so bright as to obliterate the flame of a candle at six inches from the eye.* It was extremely difficult to get the flame steady even for a second, owing to the wind.

Herr Cuillier. VITORIA, 18th July, 1860.

"Über Totale Sonnenfinsternisse," Dr. von Mädler, p. 21.

No shadow thrown by the corona, even from the largest objects.

Herr CUILLIER hatte die Form und Schärfe der Schatten zu beobachten übernommen.

Die Lichtkrone warf keinen Schatten, selbst nicht von den grössten Gegenständen.

M. Rapatel. ABOARD THE LABOURDONNAIS, BETWEEN MADRAS AND CALCUTTA, 18th August, 1868.

"Comptes Rendus," Vol. lxvii., p. 301.

All shadows disappeared from the moment of totality; the corona gave none.

Tout ombre a disparu dès l'éclipse totale, et l'auréole n'en a donné aucune.

Dr. Curtis. DES MOINES, IOWA, 17th Aug., 1869.

"Washington Observations, 1869," Appendix ii., p. 133.

The image of the corona thrown by the finder was so excessively faint,

* Mr. Beck probably means that the corona, or the brighter parts of the corona, could be seen through the flame of the candle; but it does not follow that the illuminating power of the corona was greater than that of the candle at a distance of six inches. It may be well here to remark that the brightness of a flame, area for area, is independent of its distance, and that consequently the visibility of objects seen through the flame would not be affected by the distance of the candle from the eye of the observer. Nor is the part of a dark wedge through which the flame of a candle can just be discerned, affected by the distance of the candle, so long as the flame subtends a sensible angle to the eye of the observer. At a distance of six inches from the eye the flame of a candle would subtend an angle of many degrees, both in length and breadth. It should therefore have been stated whether the corona was seen through the white or the blue part of the flame, and whether the eye was focused upon the flame or on the corona.

that at first I could see absolutely *nothing* upon the screen when the sun disappeared.

* * * * * *

I thought that I was secure against this mishap, and that the plan of receiving the image from the finder upon white card-board was safe for use during totality. I had previously carefully tested the arrangement upon the moon, whose light that of the corona was universally held to equal, and had found that I could see the image of that luminary upon the screen with perfect distinctness when standing so as to command the adjusting screws of the telescope. Whether it was that the real amount of light of the corona has been over-estimated, or whether its feebleness on this occasion was entirely due to the prevailing haze, I cannot of course positively say, but am inclined to think that most of the trouble was from the latter cause.*

Prof. C. A. Young. JEREZ, 22nd Dec., 1870.

"United States Coast Survey Report for 1870," Appendix No. 16.

(p. 29.) A small piece of card with an orifice in its centre was fastened over the slit, and no other finder was necessary, as even during the totality the image thrown upon the card was abundantly bright to enable me to point to any desired portion of the corona with perfect certainty.

Mr. Ranyard. VILLASMUNDA, 22nd Dec., 1870.

MS. Observations of the 1870 Eclipse.

(p. 17.) Before applying my eye to the finder, I gave a passing look at the corona with my undefended eyes, but was completely dazzled by its light, and the only impression which I derived was of brilliant spurious rays springing from all sides of the moon.

* The haze does not appear to have been sufficient to materially interfere with the other observations at Des Moines. Its presence was, however, noticed by Prof. EASTMAN.

Commander Maclear. BÉKUL,
12th Dec., 1871.

MS. Reports of the 1871 Expedition.

On two successive nights before the eclipse, with the 6-inch refractor and direct-vision spectroscope of seven prisms, I was able to see plainly three lines in the spectrum of the nebula in the sword-handle of Orion; and yet with the same instrument, during totality, I was unable to detect any spectrum in any part of the corona, though certainly I cannot say what width of slit I had in observing the nebula; but the lines were narrow and distinct. I do not think that the width of slit when observing the nebula could have been more than two or three times as wide as when observing the corona. I formed this opinion from having had occasion to look at the slit occasionally, and from the width of the lines in the hydrogen tube used at the same time.

CHAPTER XLII.

POLARISCOPIC OBSERVATIONS.

THE observations contained in the present chapter arrange themselves under the following heads: 1. Observations bearing on the polarization of the atmosphere within the area of totality; 2. Observations as to the polarization of the light of the prominences; 3. Observations as to the polarization of the light of the corona.

First, as to the polarization of the atmosphere. The observations of MAUVAIS in 1842, PICKERING in 1869, BECKER, CLIFFORD, SAMUELSON, PEIRCE, GRIFFITH, LOCKYER, and BROUGHTON appear to show that the light dispersed by the atmosphere in the neighbourhood of the eclipsed sun is polarized in a plane perpendicular, or not far from perpendicular, to the horizon. ROSS's observation, if the description of the position in which his instrument was set is correct, would show that the atmosphere about the corona, as seen at his station, was polarized in a horizontal plane; but it must be borne in mind that a half rotation of his instrument would be sufficient to reverse the position of the colours.

Small particles floating in the atmosphere within the area of totality would be principally illuminated (as has been shown in a former chapter) by light derived in all azimuths from the clouds and sky upon the horizon; we should therefore expect to find that the light dispersed by such small particles would be polarized in a vertical or nearly vertical plane, and that the light of the heavens in the immediate neighbourhood of the eclipsed sun, which must be derived entirely from the atmosphere within the region of the moon's shadow, would be polarized in a vertical or nearly vertical plane. Observations have not, as far as we are aware, been made to determine the distance from the eclipsed sun at which the ordinary radial polarization of the air outside the area of totality, illuminated by the light of the thin solar crescent, would overpower the vertical polarization of the atmosphere within the region of the moon's

shadow; but from SAMUELSON's observation, it appears that at a distance of 10° or 15° from the eclipsed sun, the plane of polarization was, at the time of his observation at Villasmunda, sensibly vertical.

The inclination to the vertical of the plane of the lower air polarization will, no doubt, greatly depend upon the amount of illumination received in various azimuths, and especially on the distance of the observer from the edge of the area of totality. We should expect to find the inclination of the plane to the vertical vary as the moon's shadow passes over the observer's station. But no evidence as to such variation (if we omit CLIFFORD's observation of the polarization on clouds) can be gathered from the accounts of the observations which we have collected.

MAUVAIS in 1851, LIAIS, BECK, PICKERING 1870, LADD, BLASERNA, EASTMAN, and HARKNESS all concur as to the polarized condition of the light received from the heavens in the direction of the moon's disc, or from the area immediately surrounding the corona; though none of the observations of these observers are as they are described sufficient to determine the position of the plane of polarization. LIAIS and WINTER appear to be the only observers who found the corona polarized, but were not able to detect any polarization upon the place of the moon's disc. See also LANGLEY's observations, to which, however, he does not attach much weight.

The observations of BECKER, LOCKYER, and BROUGHTON are here taken as determining the plane of the air polarization, as it appears that the fields of the instruments made use of by them were in each case several degrees in diameter, and that the breadth of the fringes of the Savarts they used must have subtended large angles compared with the apparent breadth of the moon's disc.

It appears from all the above observations, that the atmospheric polarization is sufficiently strong to overpower the radial polarization of the corona at a very short distance—probably not more than 1° from the moon's limb.*

* No observations appear to have been made in order to determine the exact distance from the sun's limb at which the polarization of the corona has an appreciable effect in disturbing the uniform polarization of the surrounding atmosphere. Let us suppose that an observer

List of Observations bearing on the Polarization of the Atmosphere during Totality.

1842.	**Mauvais.**	Savart and naked eye. Bands at maximum when horizontal.
1851.	**Mauvais.**	Instrument not described. The existence of polarization detected on the moon.
1858.	**Liais.**	Savart and naked eye. No polarization detected on the moon; faint atmospheric polarization observed at the edge of the field, but its plane not determined. With tourmaline and telescope no polarization detected on the moon.
1860.	**Beck.**	Tourmaline and crystals of salacine telescope and power of 60. Polarization detected on the disc of the moon, but its plane not determined.
1869.	**Pickering.**	Arago polariscope, unmagnified image. Corona seen on uniform background of colour; plane of polarization of sky perpendicular (query parallel) to the horizon.

has found that the air polarization about the sun's place is vertical; then, in passing along a parallel to the horizon through the sun's centre he would expect at some little distance from the limb to find the air polarization unaffected by any component due to the corona.

At such a point an observer using a Savart polarimeter would find the bands at a maximum when parallel or perpendicular to the horizon. Having carefully turned out all trace of the bands upon the centre of his field, let him now pass inward towards the sun's limb (directing his attention all the time to the centre of his field only); when he there perceives the first trace of bands, he will know that the plane of polarization has changed. If on going backwards the bands disappear again, while on passing onwards they continue to increase in intensity (the plates of the polarimeter remaining fixed), he will know that the change is due to a component introduced by the corona; and he will be able to estimate the distance from the moon's limb at which such a component first became visible.

It is possible that by such a method of observation an observer might be able to trace the corona further than he could with the unaided eye, for it would be somewhat equivalent to making the corona shine upon a black background of sky; and much more than equivalent to accomplishing this with a Nicol only, for the Savart will (with light that is not very faint) detect a much smaller admixture of polarized light than is detectable with the Nicol. On the other hand, it must be remembered that a great deal of light is lost in passing through a Savart or Nicol.

The visible outer border of the corona is where our eye first distinguishes a difference between (the light of the sky) and (the light of the sky + the light of the corona). But with the above method the visible outer edge of the corona will be where the observer first distinguishes a difference between an area of no polarization and polarization due to the corona.

In using a Savart with a large field, the central portion of the field may be marked by fixing in the principal focus of the telescope a plate of glass with a small circle etched upon it.

1870.	**Becker.**	Savart and naked eye; field of nearly 5°. Bands seen right across field, plane of polarization making an angle of 27° with the vertical.
	Pickering.	Arago and naked eye. Faint sky polarization, plane not determined. With biquartz and telescope polarization on moon's disc detected, plane not determined. With Savart faint sky polarization detected, plane not determined.
	Ross.	Arago and naked eye. Sky found to be polarized in a horizontal plane.
	Ladd.	Arragonite and double-image prism used with telescope. Evidence of polarization found on moon, plane not determined.
	Blaserna.	Savart used with telescope. Traces of polarization seen on moon, plane not determined.
	Clifford.	Babinet used with telescope. Plane of polarization on clouds near sun, inclined from 10° to 23° to the vertical. On dark moon, seen through break in clouds, vertical.
	Samuelson.	Savart and naked eye. Air polarization at points 15° and 10° from the sun, found to be in a vertical plane.
	Peirce.	Savart and telescope. Plane of polarization on two points of the corona 90° apart found to be inclined about 6° from the radial, being more nearly vertical.
	Eastman.	Savart and telescope. Traces of polarization found upon the moon's disc and upon the clouds outside the corona.
	Griffith.	Savart-polarimeter and telescope. At the central part of the moon the plane of polarization was found to be inclined 10° from the vertical towards the west, polarimeter plates turned through 32°.
	Harkness.	Arago and naked eye (query). Sky found to be polarized, plane not determined.
1871.	**Lockyer.**	Savart and telescope, large field. Vertical lines over everything—corona, dark moon, and unoccupied sky; 3 m. after totality the vertical lines were still visible.
	Broughton.	Savart and naked eye. Strong vertical bands.
	Winter.	Savart-polarimeter and telescope. No polarization observed on the moon's disc.

Observations as to the Polarization of the Light of the Prominences.

DUNKIN, D'ABBADIE in 1860, PRAZMOWSKI, CAMPBELL, and BRANFILL, all agree that the light of the prominences is not polarized. D'ABBADIE,

observing in 1851, thought that the transparent part of one of the prominences was polarized, but he adds that he was not able to detect polarization in the light of the rest of the prominence, which he speaks of as being of a red colour. It would seem, therefore, that what he describes as the transparent part of the prominence must have been some brilliant coronal structure above what is ordinarily* spoken of as the chromosphere.

D'ABBADIE's companion RIIS says that the light of the prominences appeared to him to be polarized, but it is evident that he speaks doubtfully about the prominences, as he adds that the light of the corona was certainly polarized. LOCKYER's observation as to Savart's Bands being visible in his field of view "over everything—corona, prominences, dark moon, and unoccupied sky," cannot be taken as having much weight with regard to the polarization of the prominences; for though the breadth of the bands as seen in his instrument is not mentioned, it is evident that they must have been broad compared with the apparent magnitude of the prominences, and in the course of a hurried examination it would be difficult to determine whether the light of the prominences was interfered with, as comparatively broad bands were swept over them. The system of bands would only appear broken or interfered† with upon being swept over an area of altered polarization the diameter of which was large compared with the breadth of the individual fringes.

In connection with the non-polarization of the light of the prominences

* Now that we know that the light of the corona up to a considerable altitude gives a bright-line spectrum, it is difficult to lay down any definition as to what is to be considered as the upper limit of the chromosphere.

† It may perhaps be well to remark that an area of no polarization would, if sufficiently extensive, cause the system of bands to appear broken at a part of the field corresponding to the area of no polarization, and that light polarized in a plane making an angle of 45° with the direction of the bands (as seen on the rest of the field) would also cause the bands to appear broken. Light polarized in a plane making a greater angle than 45° with the direction of the bands would cause the system of bands to appear shifted at the part of the field corresponding to the area of altered polarization, so that the dark fringes within the area would correspond and be continuous with the interspaces between the dark fringes upon the rest of the field. In all other positions of the plane of polarization, a change more or less marked in the intensity of the fringes on the part of the field corresponding to the area of altered polarization is all that would be perceived.

it should be noticed that PRAZMOWSKI, LANGLEY, and WINTER * agree in estimating that the polarization of the light of the corona increases in intensity on proceeding outwards from the moon's limb, until at a certain distance the maximum intensity of polarization is attained.

Now that we know from the evidence afforded us by the spectroscope that the light of the prominences, and also a part of the light of the lower corona, is emitted by gas in a state of incandescence, we might have predicted that the light of the prominences would be found to be unpolarized, and that the light of the lower corona would be found to be less strongly polarized than that derived from higher parts of the corona, from which no bright-line spectrum, or only a very faint bright-line spectrum, is obtained; but it does not necessarily follow that the whole of the observed difference in the intensity of polarization in passing from the coronal area adjacent to the sun's limb to the altitude of maximum polarization is due to the admixture of emitted light with light dispersed by the corona at the lower level. For assuming, as we doubtless may, that the polarization of the corona is due to the dispersion of the light of the sun by dust, the particles of which are small compared with the wave length of light,† it is possible that in the lower parts of the corona there may be a greater proportion of particles whose diameter is large compared with the wave length. Or again, the minute particles which disperse the light in the lower corona may be incandescent, or more intensely incandescent than those in the higher parts of the corona.

A theoretical consideration of the amount of polarization which should be observed in light derived from different parts of the corona—on the assumption that the light-dispersing particles are uniformly distributed

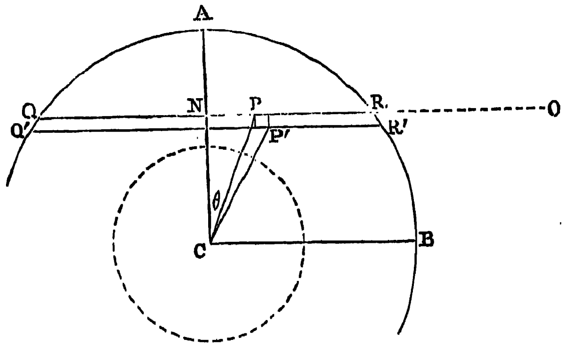
* Prazmowski says: "As far as I remember, the part of the corona on which the colours were strongest did not correspond to the most luminous part, but was situated at a certain distance from the limb of the moon." Langley says that the bands (he was using a Savart) could not be "followed up to the moon's limb, and their increasing faintness as they approached it was noticed." Winter measured with a polarimeter the intensity of the polarization, first close to the moon's limb, and then at a distance of about 10′ from the limb, and found that the polarization was much more intense at the latter distance.

† This cause of polarization, which is sensibly complete for rays perpendicular to those incident, was we believe first pointed out by Professor Stokes in his paper "On the Change of Refrangibility of Light," published in the Philosophical Transactions for 1852. (See §§ 182 and 183, p. 530.)

within a spherical area about the sun—shows that if the particles are all small, and are not incandescent or suspended in an area of incandescent gas, the polarization should be greatest in intensity near to the apparent outer limits of the corona; and the amount of polarization should decrease uniformly from the outer limit of the corona inwards towards the sun's limb.* But no doubt the distribution of the polarizing particles is not

* Let QARB be the outer limit of the corona; C, the sun's centre. The coronal matter within an elementary area PP′ will be lit up by light derived from all parts of the sun's surface.

Let us first consider the problem as if the sun's light emanated from a luminous point at C. A particle at P will be subjected to ethereal agitations in a plane perpendicular to CP, and will become the centre of secondary waves. We may consider the agitations as resolved into two sets—one parallel and one perpendicular to the plane CPO. Since the agitations we perceive as light are all perpendicular to the direction of propagation, only a part of the agitation to which the particle at P is subjected, in the plane CPO, will produce any effect as light in the direction PO, but the whole of the agitation perpendicular to the plane CPO will be propagated in the direction PO. Let α be the amplitude of the agitation at a unit of distance produced by the light emanating from C. Draw CA perpendicular to OP, meeting OP in N. Let the angle PCN $= \theta$, and let CN $= x$. Then, since the intensity of the sun's light at P varies inversely as CP², the amplitude of the agitation at P varies inversely as CP, and the amplitude of the agitation in the plane of the paper propagated in the direction PO by a particle at P, will be



$$a.\frac{\cos\theta}{x}.\sin\theta$$

And if β be the amplitude of the total agitation in the plane of the paper of the light dispersed in the direction PO by particles within an elementary area RR′Q′Q, we shall have

$$\beta^2 = 2\int_0^{x\tan\theta} a^2.\frac{\cos^2\theta}{x^2}.\sin^2\theta\,d\,(x\tan\theta) = \frac{2a^2}{x}\int_0^{\theta}\sin^2\theta\,d\,\theta$$

$$= \frac{a^2}{x}\int_0^{\theta}(1-\cos 2\theta)\,d\,\theta = \frac{a^2}{x}\left\{\theta - \sin\theta\,.\cos\theta\right\}$$

uniform, as we have assumed. An examination of the photographs taken during the various eclipses shows that the coronal light diminishes rapidly beyond a certain limit, and it should be remembered that the fringes or colours produced by the comparatively strong polarization of a very faint light would not be so easily perceived as those produced by a less degree of polarization of a stronger light. The problem is also complicated by the superposition of the polarized light of the atmosphere. WINTER's observation was made on a part of the corona where the polarization of the atmosphere, assuming it to be vertical, would have tended to efface the radial polarization of the corona, and consequently the difference in the intensity of the Savart's bands seen on the two parts of the corona must have been rendered more striking than it would have been if the light of the corona had alone been observed.

And if γ be the amplitude of the total agitation perpendicular to the plane of the paper of the light dispersed in the direction PO by particles within the elementary area RR'Q'Q, we have

$$\gamma^2 = 2\int_0^{x\tan\theta} a^2 \frac{\cos^2\theta}{x^2}\, d\,(x\tan\theta) = \frac{2a^2}{x}\int_0^{\theta} d\,\theta = \frac{2\theta}{x}\,a^2$$

And if p be the ratio of the amplitude perpendicular to the plane of the paper to the amplitude in the plane of the paper of the light dispersed in the direction PO by the particles within an elementary area RR'Q'Q, we have

$$p = \sqrt{\frac{2\theta}{\theta - \sin\theta\,.\,\cos\theta}}$$

At A, the outer apparent limit of the corona, $\theta = 0$ and the above ratio takes the form $\frac{0}{0}$; differentiating numerator and denominator we have at the outer apparent limit of the corona

$$p = \sqrt{\frac{2}{1 - \cos^2\theta + \sin^2\theta}} = \sqrt{\frac{1}{\sin^2\theta}}$$

or p is infinite; that is, the light derived from the corona at its outer apparent limit A will be completely polarized.

At B, the central part of the corona, which would be hidden by the moon's disc during a total eclipse,

$$\theta = \frac{\pi}{2} \text{ and } p = \sqrt{\frac{\pi}{\frac{\pi}{2} - 0}} = \sqrt{2}$$

List of Observations bearing on the State as to Polarization of the Light of the Prominences.

1851.	D'Abbadie.	Quartz plate and double-image prism used with telescope, power 52. Transparent part of prominence strongly polarized.
	Riis.	Rochon polariscope used with telescope, power 25. Light of the prominences appeared to be polarized. Corona certainly polarized.
	Dunkin.	Double-image prism used with telescope, power 38. Could not perceive any difference in the brightness of the two images.
1860.	D'Abbadie.	Quartz plate and double-image prism of small angle of separation, used with telescope, power 47. No trace of polarization detected.
	Prazmowski.	Quartz plate and double-image prism, angle of separation $1\frac{1}{2}'$,

At first sight it might appear that at the central part of the corona the light should be entirely unpolarized, but it must be remembered that the illumination of the particles adjacent to C will be very great, and the polarization of the light dispersed by them will, it appears, overpower the non-polarization of the light dispersed by the higher parts of the corona.

The differential coefficient of p is negative from $\theta = 0$ to $\theta = \frac{\pi}{2}$,

$$\frac{dp}{d\theta} = \frac{1}{2}\sqrt{\frac{\theta - \sin\theta \,.\, \cos\theta}{2\theta}} \,.\, \frac{2\,(\theta - \sin\theta \,.\, \cos\theta) - 4\,\theta\sin^2\theta}{(\theta - \sin\theta \,.\, \cos\theta)^2}$$

for $\sin\theta \,.\, \cos\theta$ is always less than θ, and $2\,(\theta - \sin\theta \,.\, \cos\theta) - 4\,\theta \,.\, \sin^2\theta$ is always negative, for when $\theta = \frac{\pi}{2}$, $2\,(\theta - \sin\theta \,.\, \cos\theta) - 4\,\theta \,.\, \sin^2\theta = -\pi$, and the expression only vanishes when $\theta - 2\,\theta \,.\, \sin^2\theta = \sin\theta \,.\, \cos\theta$, or when $\theta = \frac{\sin\theta \,.\, \cos\theta}{1 - 2\sin^2\theta} = \frac{1}{2}\tan 2\,\theta$, which is only true at the limit $\theta = 0$.

Therefore $\frac{dp}{d\theta}$ is always negative, and the intensity of the polarization regularly diminishes from the outward apparent limits of the corona inwards.

And if we take into account the angular magnitude of the sun's disc, it is evident that the intensity of the polarization of the light dispersed by particles within an elementary area PP in the direction PO will be less than if the sun's light were derived from a luminous point at C. And the decrease in the intensity of the polarization will be greater the greater the angular magnitude of the sun's disc. As seen from P, therefore, the coronal polarization will (when we take into account the magnitude of the sun's disc) still increase in passing from B outwards to A.

		used with telescope, power 44. Light of prominences found to be unpolarized.
1868.	**Campbell.**	Quartz plate and double-image prism used with telescope, power 27. No polarization detected in the light of the remarkable horn-like protuberance.
	Branfill.	Savart used with telescope. No bands seen on the great horn-like protuberance.
1871.	**Lockyer.**	Savart used with telescope and low-power eyepiece. Bands seen over everything—corona, prominences, dark moon, and unoccupied sky.

Observations as to the Polarization of the Light of the Corona.

The observations of those who have endeavoured to determine the state as to polarization of the light of the corona may be classified under four heads:—

a. Observations of those who have been unable to detect any traces of polarization.

b. Observations of those who have found the light derived from the coronal area to be polarized, but who have not determined the plane of its polarization.

c. Observations of those who have determined the plane of polarization, on some part of the corona, and have found it not to coincide with the normal to the sun's limb.

d. Observations tending to show that the corona is polarized radially with respect to the sun.

(*a*) Of the fifty-two observers whose observations are collected in the present chapter, sixteen were unable to discover traces of polarization in the light of the corona, and of these fifteen were unable to discover any traces of polarization in the light of the corona, together with the light derived from the area of sky about the sun's place occupied by the corona; but the value of their evidence is considerably diminished when we consider the following facts.

Carrington, Pickering 1869, Fison, Adams, and Harkness were only able to devote a few moments to a hurried examination of the phenomena visible in their instruments.

Carrington, Lindelöf, Pickering, Ross, Harkness, and query

also SOUZA, LATOURNEUR, and BÉHIC, examined the unmagnified image of the corona. PICKERING, however, examined the light of the corona again in 1870, and then found evidence of strong polarization.

PINAUD, BOISGIRAUD, BARTH do not describe the instruments they used, and RENNENKAMPFF made use of an instrument totally unsuited for his purpose.

DUNKIN, LINDELÖF, MOULTON, FISON, and ADAMS observed the corona through clouds, the small particles of which would no doubt tend to depolarize the light by superposing that derived from different portions of the corona.

List of Observers who have failed to detect evidence of Polarization on examining the Light of the Corona.

1842.	Pinaud. Boisgiraud.	Instrument not described. No colours perceived upon the corona or on the neighbouring sky.
1851.	Dunkin.	Nicol's prism. Corona just visible through clouds. No polarization detected.
	Carrington.	Nicol's prism and plate of crystal made use of for an instant without a telescope. No polarization detected.
1860.	Lindelöf.	Arago polariscope held in the hand. Corona seen through clouds. No polarization detected.
	Barth.	Instrument not described. No polarization detected.
	Rennenkampff.	Unsuitable instrument. No polarization detected.
	Souza.	Arago polariscope (query without a telescope). Not the least trace of polarization found.
1868.	Latourneur.	Savart (query without a telescope). Negative result.
	Béhic.	Arago polariscope (query without a telescope). Negative results.
1869.	Pickering.	Arago polariscope, unmagnified image, hurried observation. Atmospheric polarization detected, but not that of the corona.
1870.	Moulton.	Telescope with Babinet's wedges. Corona seen through clouds. No polarization detected either on corona, on clouds outside corona, or on moon's disc.
	Ross.	Arago polariscope without telescope. Sky polarization detected, but corona appeared perfectly white.
	Fison.	Telescope and double-image prism. Corona seen through clouds, for about 15 sec.; could not observe with certainty whether there was any difference of tint between the two images.

Adams.	Telescope, biquartz, and Nicol. Corona just seen through clouds. No polarization detected.
Harkness.	Arago polariscope used without telescope; hurried observation. Atmospheric polarization detected extending over the place of the corona; polarization of light of corona not detected.

(*b*) The observations of twelve of the observers may be ranked in our second class. Among these MAUVAIS, BECK, and LADD, state that the fringes or colours observed by them on the coronal area were more intense than those seen by them on the area occupied by the disc of the dark moon—a fact which is sufficient to show that the polarization of the light derived from the area occupied by the corona must be chiefly due to the polarization of the light of the corona itself,* and cannot be due to the polarization of the light dispersed by the veil of intervening atmosphere.†

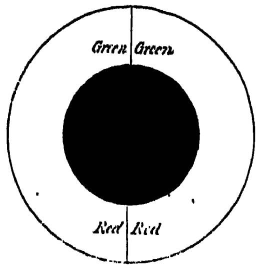
If the polarization of the area about the sun's place, as observed during totality, were due solely to the polarization of the atmosphere under its altered conditions of illumination, we might expect to find that the addition of the unpolarized light of the corona to the polarized light of the atmosphere would cause the polarization of the area occupied by the corona to be much less easily distinguished than the polarization of the surrounding area of sky, or than that of the area of the dark moon. But the contrary appears to be the case. MAUVAIS, in 1842, GABBA, D'ABBADIE, BECK, BARREDA, and LADD, all concur in asserting that the light from the coronal area appears strongly polarized. BECK says that the polarization of the corona "surpassed in brilliancy" that seen at about 90° from the sun. WINTER, in 1868, says that the bands observed by him upon the corona were more vivid than any he had observed on a clear sky; and BLASERNA, whose observation was made through drifting clouds, estimated that the bands seen by him upon the

* It cannot be supposed that the light of the corona becomes polarized on entering our atmosphere, for the light of the sun is not found to be polarized under similar circumstances.

† Griffith also, whose observation is discussed under our next heading, mentions that the intensity of the polarization of the light of the corona "seemed to be much higher than that on the moon's surface." On measuring the intensity with a polarimeter, he found that when examining the light from the centre of the moon's disc the plates of his instrument needed to be rotated through only 32° in order to obliterate the bands due to the atmospheric polarization; while in examining the light of the corona at one point the plates needed to be rotated through 37°, and at another through 39°.

corona were equal in intensity to those seen upon a clear sky in ordinary daylight, at 50° from the sun. There can be little doubt, therefore, that the polarization of the coronal area does not appear less intense than the polarization of the surrounding area of sky; and if it be granted that the light of the corona is polarized, it will at once be seen that we can hardly conceive of its being so in any manner except in planes symmetrically arranged with regard to the sun's centre.

LOCKYER's observations, both with his Savart and biquartz, show the existence of polarization on the area occupied by the corona. The wedges of colour as seen with his biquartz may possibly be accounted for by the fact that on the parts of the heavens corresponding to the great V-shaped rifts the atmospheric polarization would have a greater effect in modifying the plane of coronal polarization than on the denser and more luminous parts of the corona. MR. LOCKYER informs us that, as far as his memory serves him, the line of junction of his biquartz was vertical, bisecting the dark moon, and consequently the great V-shaped polar * rifts (shown in the steel plates of the 1871 corona) must have been near to the centre of the field in each plate of his biquartz. On the assumption of radial polarization, with a biquartz set so as to give the sensitive blue tint on both halves with light polarized in a plane parallel to the line of junction, we should have a green † area seen near to the line of junction above the moon, and a red area seen near to the line of junction below the moon, and the green would pass through yellow into red on either side; but the brownish colour spoken of is difficult to account for, since brown is not one of the series of colours seen when polarized white light is examined with a quartz-plate and an analyser.



* The eclipse took place early in the morning, and consequently the sun's axis was not greatly inclined to the horizon, as seen from Békul.

† The reason of this is, that in passing away from the line of junction the tints change rapidly on either side. Above the moon the colours pass from blue through the various tints of green, and below from blue through red-purple to red. The area in which the plane of polarization is sensibly parallel to the line of junction (on which the blue tint should be observed), is so small that observers fail to notice it; and their attention is only attracted by the fact that the green tints above and the red below merge into one another. See the observations of Prazmowski and Ranyard.

Observations of those who have found the light derived from the coronal area to be polarized, but who have not determined the plane of its polarization.

1842.	**Arago.**	Arago polariscope; hurried naked-eye observation. Corona and also the region of the dark moon showed complementary colours.
	Mauvais.	Savart polariscope; naked-eye observation. Bands at maximum when horizontal. Very strong on corona, and beyond the corona; less distinct on moon.
	Gabba.	Instrument not described. Light of corona polarizable.
1851.	**D'Abbadie.**	Arago polariscope, used with telescope. Corona strongly polarized.
	Riis.	Double-image prism and quartz plate (query), used with telescope. Light of corona certainly polarized.
	Mauvais.	Instrument not described. Polarization found upon the moon as well as on its surroundings.
1860.	**Lindhagen.**	Arago polariscope, used with telescope. Corona seen through clouds; faint differences between the images could possibly just be perceived.
1860.	**Beck.**	Crystals of salacine and tourmaline, used with telescope power 60. No polarization detected before totality. During totality strong polarization observed on corona; fainter on dark moon.
	Barreda.	Instrument not described. Light of corona very strongly polarized.
	Capello.	Savart polariscope. Light of corona found to be polarized.
1870.	**Ladd.**	Plate of arragonite and double-image prism, with telescope power 40. Polarization detected about a minute before totality, stronger on corona than on dark moon.
1871.	**Lockyer.**	With Savart and telescope, lines over everything. With biquartz and telescope, wedges faintly coloured.

(*c*) LEWIS, HUDSON, and GRIFFITH, are the only observers whose observations tend to show that the polarization of the corona is not radial. In considering their observations it will be noticed with regard to LEWIS, first, that he did not proceed to determine the part of the corona to which his telescope was directed till half an hour after totality was over, and secondly, that the position of the plane of polarization which he deduces depends on the position of his instrument at the time when Babinet's bands were seen to disappear. But since his observation was made through clouds, it is possible that the bands may have disappeared owing to the depolarization of the light of the corona by the passing clouds, rather than to the position into which his Babinet's wedges had been brought by rotation. LEWIS, it will be seen, examined the polarization of

the corona again in 1871; and upon the second occasion, when the sky was perfectly clear, he fully satisfied himself that the light of the corona was radially polarized.

HUDSON's observation was made through a break in clouds, and the plane of polarization which he gives depends upon the position of his double-image prism and slit at the time when the two images of his slit appeared to be of equal brightness. He is careful to remark that he "did not determine the plane" of polarization, but that it must have been inclined at 45° to the horizon, since the two images were of equal intensity when the diaphragm was vertical. But it will be seen that if the clouds act as depolarizers, this conclusion is not warranted. There appears, too, to be some uncertainty as to polarization produced within his instrument. His observations of polarization observed on the face of the bright moon at night, and of the polarization observed within a radius of the uneclipsed sun, seem to show that observations made with his instrument must not be relied upon until some satisfactory explanation of the cause of these extraordinary observations has been given.

GRIFFITH mentions that in his first observation upon the light of the corona "he experienced more than usual difficulty in determining the plane" of polarization, and that in his second observation "the difficulty was still greater." It is possible that, since he did not make use of a diaphragm for the purpose of confining his attention to the centre of his field of view, the bands may have been brought to a maximum, or turned out, as the case may be, upon some part of the field other than the centre; and with a large field this may have given rise to considerable error. It will be noticed that the plane determined at the first observation differs only 10° from the radial.

List of Observations tending to show that the Corona is not radially polarized.

1870.	**Lewis.**	Babinet's wedges used with telescope. Small field; hurried observation made through break in clouds. Polarization found to be in a vertical plane, on a part of the corona 9′ or 10′ from this limb, and 30° west of the vertex.
	Hudson.	Double-image prism used with telescope. Corona seen through clouds. Polarization detected on corona near vertex. Slit vertical when the two images were of equal intensity.

Observations of those who have found the light derived from the coronal area to be polarized, but who have not determined the plane of its polarization.

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	Hudson.	Double-image prism used with telescope. Corona seen through clouds. Polarization detected on corona near vertex. Slit vertical when the two images were of equal intensity.

Griffith. Savart polarimeter used with telescope. Corona seen through break in clouds. On extreme south portion of the corona, plane of polarization made an angle of 10° with the vertical towards the west. At 135° from the vertex towards the west, plane of polarization inclined 3° to the vertical.

(*d*) With the exception of LEWIS, HUDSON, and GRIFFITH, whose observations have been discussed above, it will be seen that all the observers who have determined the plane of polarization of the light derived from any part of the coronal area agree in finding that the light is radially polarized.* CAMPBELL, BRANFILL, WINTER, LANGLEY, BLASERNA, PEIRCE, EASTMAN, WINTER, and TUPMAN, who all made use of Savart polariscopes upon magnified images of the corona, agree that the bands appeared at their maximum intensity when either radial or tangential to the moon's limb.

LIAIS, observing in 1858, noted that as he turned his tourmaline the light of the corona and its rays † was dimmed in the direction of the axis of the tourmaline—an observation which affords proof of the radial character of the polarization—though it may no doubt be urged that the proof is not of a very satisfactory nature, owing to the difference in brightness of different parts of the corona, and to the difficulty of speaking with certainty as to the relative intensity of the light of areas which cannot be seen side by side in the same field of view. The observation of Prazmowski, in 1860, is, however, of a much more satisfactory nature. There is some little ambiguity about the colours observed by him on the two segments of the corona; but there can be no doubt, from his description,

* Hudson and Moulton have suggested that the polarization phenomena observed during eclipses may all be due to polarization, caused by reflexions or refractions, taking place within the instruments of the several observers; but it will be seen that Langley, Ranyard, and Lewis mention that they examined their instruments either before or after their observations, and found that there was no trace of instrumental polarization to be detected. It is also evident, from the accounts given by several other observers, that no instrumental polarization could be detected in their instruments: *vide*, *e.g.*, the observations of Beck, Ladd, and Tupman, who assert that up till shortly before totality no polarization could be detected with their instruments on the area afterwards occupied by the corona. It seems also impossible to suppose that other observers would have omitted to notice such polarization, if it had been as perceptible as that observed by them during totality.

† This observation seems to be sufficient to prove that the rays seen by Liais were not spurious rays caused by the intense light of the prominences, but were really referable to coronal structure.

that the areas adjacent to the line of junction, as it was placed bisecting the moon's disc, were polarized in planes parallel to the line of junction—that is, normal to the sun's limb. And this was found to be the case for all positions of his biquartz, as the line of junction was made to revolve, always passing through the centre of the moon's disc.

My own observation in 1870 was a repetition of PRAZMOWSKI's, with a few additional details. The second part of my observation shows that when the line of junction was moved parallel to itself, so as to cut off an arc of about 90° from the moon's limb, the plane of polarization of the coronal area adjacent to the line of junction in its new position was no longer parallel to the line of junction, but made a considerable angle with it. The third part of the observation shows that the polarization of the area of the heavens occupied by the corona was not in this instance uniformly radial. The red ray and the difference of colour on either side of the line of junction at the eastern limb may possibly be accounted for, as we have already suggested in the case of LOCKYER's observation, by the consideration that the polarization of the light derived from any part of the area occupied by the corona will be compounded of the coronal polarization as it enters the earth's atmosphere and the polarization of the light dispersed by the veil of air intervening between the corona and the observer. The intensity of the polarization, as well as the position of the resultant plane of polarization of any part of the coronal area, will no doubt depend upon the intensity of the light dispersed by the corresponding area of the corona; and consequently in a rift, or at the edge of a marked group of coronal structure, we should expect to find a sudden change in the observed polarization. This theory is supported by the fact that the place of the red ray * observed appears to correspond with the

* The difference between the colours seen on either side of the line of junction on the moon's eastern limb, will also be accounted for when we consider that at Villasmunda at the time of totality the north point was about 26° to the west of the vertex. The line of junction would therefore, if parallel to the horizon, pass across the field of view from about the point marked 110° to the point marked 290° (see the steel plate of the Syracuse photograph); and consequently it would be about coincident with the northern edge of the rift extending from 110° to 130°. We should thus have the air polarization on one side of the line of junction producing a greater effect in modifying the radial coronal polarization than on the other side; and hence the difference between the colours.

The green colour observed upon the area adjacent to the line of junction corresponding to

place of the great southern rift shown in the plates of the Cadiz and Syracuse photographs.

The action of the atmospheric polarization in modifying the plane of the coronal polarization may also be recognized in the case of PEIRCE's observation. He determined the plane of polarization on two parts of the coronal area 90° apart, and found that in each case the plane of polarization "was about 6° from the radial position, being more nearly vertical." LANGLEY and TUPMAN both note that the radial polarization of the coronal area could be easily observed at a distance of about 40′ from the limb. TUPMAN found that the coronal polarization was distinctly observable "possibly 30 seconds after totality." LADD, in 1870, detected coronal polarization springing up "about a minute before the total phase came on." TUPMAN, "a quarter of an hour or ten minutes before the total phase," could detect no traces of polarization. From LOCKYER's observation, it is evident that vertical atmospheric polarization was visible three minutes after the eclipse was over.

Observations tending to show that the Corona is radially polarized with respect to the Sun.

1858.	**Liais.**	Small telescope with a tourmaline between the eyepiece and the eye. A general dimming of the light of the corona in the direction of the axis of the tourmaline was observed, as the tourmaline was turned completely round.
1860.	**Prazmowski.**	Telescope with biquartz in the principal focus. Line of junction vertical, bisecting the moon. Brilliant colours observed on the corona. The two segments not uniformly coloured, but the areas adjacent to the line of junction of the same tint on either side, both above and below the moon. On rotating the line of junction, the colours were observed to revolve with it.
1868.	**Campbell.**	Savart and telescope. Corona observed through clouds. Bands seen normal to the moon's limb on turning the polariscope in its

the rift can only be accounted for on the above supposition, by supposing that the air polarization was inclined from the vertical towards the east; and this is just what might be expected shortly before the end of totality, when the observer would have an illuminated horizon nearer to him on the west than on the east. The red colour seen on the area corresponding to the lower great rift shows that it was not an area of no radial polarization, but that there must have been matter within the rift giving radially polarized light of sufficient intensity materially to modify the plane of the air polarization.

cell. The bands appeared to revolve on their own centre, travelling bodily along the limb. With higher power and smaller field bands appeared brighter than before, and tangential to the limb.

Branfill. Savart and telescope. Corona found to be clearly polarized in a plane passing through the sun's centre.

Winter. Savart and telescope. Corona very strongly polarized in a plane passing through the sun's centre. Bands extremely vivid—more so than in a clear sky.

1870. **Langley.** Savart used with telescope. The moon's disc appeared to cover four of the bands. In all positions the band normal to the limb was the most marked. Polarization traced to a distance of 40′ from the limb.

Pickering. Double-image prism and selenite. Naked eye: colours on corona showing radial polarization. Biquartz and telescope: corona seen through clouds; faint colours showing radial polarization. Savart and naked eye: bands seen on corona much stronger than on sky. When turned, they disappeared on sky, but remained on corona.

Blaserna. Savart and telescope. At three points on the corona near to the sun's limb, polarization found to be either radial or tangential. At a distance of 30′ no polarization detected.

Ranyard. Telescope with biquartz in the principal focus. 1. Line of junction vertical, bisecting the moon; vivid colours seen on the corona green and green contiguous to the line of junction above the moon, red and red below. 2. Line of junction shifted parallel to itself till it cut off an arc of 90° from the moon's eastern limb; green and red contiguous to line of junction above, red and green below. 3. Line of junction horizontal, bisecting moon; on the right hand green and green contiguous to line of junction; on the left hand red above and green below. Red ray, with sharply-defined edges, seen in the place of the great rift.

Peirce. Savart and telescope. Polarization on two parts of the corona 90° apart, found to be nearly radial, being inclined 6° more towards the vertical.

Eastman. Savart and telescope. Instrument moved round the corona so as to keep the lower and denser portions of the corona near the middle of the field. Bands found to be a maximum when normal and tangential to the moon's limb.

1871. **Winter.** Telescope and Savart polarimeter. Corona close to the moon's southern limb found to be polarized in a radial plane. At a distance of 10′ from the limb the amount of polarization was found to be considerably greater.

Lewis. Telescope with a pair of Babinet's wedges in the principal focus. Instrument moved round the corona at a distance of 6′ or 7′ from the moon's limb. Bands were observed to fade and reappear in a manner indicating radial polarization.

Tupman. Telescope and Savart, ten seconds after totality was over. At 45° from the vertex, bands visible to a distance of 40′ from the moon's limb; at a maximum when radial. Near the vertex, 30 seconds after totality, they were also a maximum when radial.

M. Arago. 42° 41′ 43″ N. } PERPIGNAN, 2° 53′ 50″ E. } 8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 402.

Instrument.—Double-image prism and plate of crystal used with the naked eye.

he sky about e corona, the orona itself, and ven the region f the dark moon, ound to show olours which ndicated polari- ation.

Quelques secondes seulement nous séparaient alors de la fin de l'éclipse totale: il n'y avait pas de temps à perdre. Je saisis sur-le-champ un polariscope à lunules placé à côté de moi; je remis à M. Victor Mauvais un polariscope à bandes colorées, et je me mis à explorer, avec mon instrument, les environs de l'auréole lumineuse, l'auréole elle-même, et jusqu'à la région atmosphérique qui se projetait sur le disque de la Lune. Partout je vis les deux lunules teintes de ces couleurs complémentaires qui indiquent, d'une manière infaillible, la présence de rayons polarisés dans tout faisceau soumis à l'analyse délicate de l'instrument. Je n'eus pas le temps de pousser les observations plus loin.

M. Victor Mauvais. 42° 41′ 43″ N. } PERPIGNAN, 2° 53′ 50″ E. } 8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 404.

Instrument.—Savart used with the naked eye.

With Savart naximum of ntensity when he bands were iorizontal. They were very listinct on the corona, and were also seen, though ess distinctly, on the moon.

Pendant l'éclipse totale j'ai dirigé sur la Lune et sur la couronne le polariscope dit de Savart, et j'ai vu les bandes irisées. Le maximum d'intensité correspondait à la position horizontale de ces bandes; elles étaient très-vives sur la couronne et au delà; elles paraissaient moins prononcées sur la Lune même. Cependant on les voyait distinctement.

M. Pinaud. 43° 10′ N.⎫ NARBONNE,
M. Boisgiraud. 3° 0′ E.⎭ 8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 405.

Instrument.—Not described.

Nous n'avons trouvé aucune trace de polarisation dans la lumière de l'auréole qui environnait le limbe de la Lune pendant l'éclipse totale. Le polariscope dirigé vers cette auréole et dans les régions voisines, n'a donné aucune coloration sensible. The polariscope directed towarc the corona and the neighbourin regions gave nc traces of colour

Prof. Majocchi. 45° 25′ N.⎫ MILAN,
Prof. Gabba. 9° 10′ E.⎭ 7th July, 1842.

"Annalen der Sternwarte in Wien," Vol. ii., Neue Folge, p. xxxix.

Majocchi's Instrument a double-image prism. *Gabba's Instrument* not described.

Das Licht des Silberringes ist, wie es nämlich meinem Collegen Professor Gabba schien, der Polarisation fähig, obgleich ich selbst keines der beyder Bilder im doppelt brechenden Prisma wahrnahm, als ich auf einen Augenblick an's Instrument ging, und durch Drehung des Prismas mich zu überzeugen suchte, ob eines der Bilder verschwinde, um so Gewissheit von der Polarisations—Fähigkeit des Lichtes zu erhalten. Mein Auge so eben der Einwirkung des concentrirten Lichtes im Telescope ausgesetzt, war wahrscheinlich zu unempfindlich fur diese Erscheinung, welche mein College wahrnahm. Gabba found the light of the corona polarizable. Majocchi was unable to perceive either of the images with a double-image prism.

M. Antoine d'Abbadie. 58° 59′ 33″.9 N.⎫ FREDERIKSVŒRN,
10° 3′ 52″ E.⎭ 28th July, 1851.

"Comptes Rendus," Vol. xxxviii., p. 295.

Instrument.—Telescope 3·9 in. aperture and power of 52, with a quartz plate and double-image prism.

Ma lunette avait 99 millimètres d'ouverture, et grossissait cinquante-deux fois; . . . . J'en fis un polariscope, en insérant une plaque de quartz entre l'objectif et l'oculaire, et employant un prisme biréfringent comme analyseur. L'auréole était fortement polarisée. (p. 296) La lumière qui venait de la partie transparente de cette protubérance était fortement Corona strongly polarized. Transparent part of prominence strongly polarized. Polarization of rest of prominence not detected.

polarisée; sur la portion voisine, restée toujours rose, la polarisation était plus faible, ou du moins elle ne se manifestait que par une renforcement de teinte, car, par malheur, ma plaque de quartz avait été taillée pour donner du rouge.

M. Riis. 58° 59′ 33·9″ N., 10° 3′ 52″ E. } FREDERIKSVŒRN, 28th July, 1851.

"Comptes Rendus," Vol. xxxviii., p. 297.

Instrument.—Double-image prism and plate of crystal. (Query.)

J'avais confié ma* lunette de Rochon à M. RIIS, officier de la marine royale de Norvége. Cette lunette polariscope avait 29 millimètres d'ouverture, et grossissait vingt-cinq fois . . Je ne pouvais, dit M. RIIS, voir ni fibre ni ligne radiale dans l'auréole. Autour de la Lune obscure était un anneau beaucoup plus étroit, d'un gris foncé, bien net, distinct de l'anneau intérieur et tout juste assez large pour être visible. En dehors de ce mince et sombre anneau, le reste de l'auréole était d'un blanc grisâtre. Toutes ces couleurs changeaient d'intensité, visiblement, mais peu à mesure que je tournais l'instrument sur son axe. La lumière des protubérances me paraissait polarisée: celle de la couronne l'était certainement.

Mr. Dunkin. 59° 54′ 5″ N., 10° 43′ 28″ E. } CHRISTIANIA, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., pt. i., p. 12.

Instruments.—A doubly refracting prism and a Nicol's prism made use of, with a refracting telescope.

My observations of the corona are very unsatisfactory: of all the phenomena the clouds affected it most. Traces of it were seen on the whole of the apparent east limb, but on the opposite side of the moon only confused patches of light were visible . . . . No traces of polarization could be perceived.

(p. 13.) [I also examined the light from a prominence 70° from the vertex towards the east, as seen in an inverting telescope; but] with the doubly-refracting prism I could not perceive any difference in the brightness of the two images.

* The description of the observation is by M. d'Abbadie.

Mr. Carrington. 58° 7′ N. } LILLA EDET,
12° 8′ E. } 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., pt. i., p. 63.

Instrument.—Nicol's prism and plate of crystal.

I had the curiosity to try the Nicol's prism on the corona for an instant, but could not perceive any traces of polarization. It is necessary to add that I took the precaution to ascertain that the instrument was in a proper state, exhibiting the usual rings and brushes readily when directed to the blue sky at a sufficient distance from the sun.

Instrument made use of for an instant; no traces of polarization perceived.

M. Mauvais. 54° 20 58 N. } DANTZIG,
18° 40′ 15″ E. } 28th July, 1851.

"Comptes Rendus," Vol. xxxiii., pp. 127-8.

Instrument.—Not described.

J'ai pu constater l'existence de la polarisation tant sur la Lune même que sur son contour, mais avec des aspects si entremêlés de couleurs diverses, que j'ai éprouvé bien des difficultés pour en mesurer l'intensité.

I was able to prove the existence of polarization on the moon itself as well as on its surroundings.

Dr. Em. Liais. 25° 30′ 33″.24 S. } PARANAGUA,
48° 26′ 58″.95 W. } 7th Sept., 1858.

"Astr. Nachr.," Vol. xlix., p. 288.

Instruments.—1. Small telescope with a tourmaline between the eyepiece and eye of the observer. 2. A Savart used with the naked eye.

M. LIAIS a regardé la couronne dans sa lunette en interposant une tourmaline entre l'œil et l'oculaire. Il a alors remarqué un affaiblissement général des rayons et du fond de la couronne, dans le sens de l'axe de la tourmaline. Cet affaiblissement était peu prononcé, mais bien sensible.

En faisant tourner la tourmaline, cet affaiblissement dans le sens de l'axe, fut remarqué tout autour du soleil, et paraissait avoir lieu de même pour les rayons de la couronne de toute nature. La région de la lune ne semblait pas, au contraire, changer d'intensité, ce qui prouve qu'il n'y avait pas de polarisation atmosphérique bien appréciable dans cette direction.

Observed with a tourmaline between the eye-piece and the eye, the corona was seen to be dimmed in the direction of the axis of the tourmaline. With the naked eye and a Savart, feeble bands were seen on the corona. None were detected on the moon, but faint atmospheric polarization was observed at the edge of the field.

Le même observateur jeta ensuite à l'œil nu, et avec le polariscope

Savart, un regard rapide sur l'atmosphère dans la région de la lune. Il remarqua quelques traces de bandes sur la couronne, rien d'appréciable dans les environs et sur la lune. Les bandes étaient tres-faibles sur la couronne, et leur coloration n'était pas sensible. Aux extrémités du champ du polariscope commençait la polarisation atmosphérique, mais son sens n'a pas été determiné au-dessous et au-dessus de la lune. Vu la faiblesse de la lumière, cette observation aurait pris trop de temps.

Il resulté de ce qui précéde que la couronne est polarisée mais faiblement.

Dr. L. Lindelöf. 42° 58′ 12″ N., 3° 53′ 15″ W. BEZANA, SPAIN, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

Instrument.—An Arago polariscope; apparently used with the naked eye.

The sun was covered with light clouds. No polarization was detected.

Pendant l'éclipse totale il y avait devant le soleil des nuages legers, qui n'empêchaient pas cependant de voir assez bien l'auréole et les protubérances; mais peu de temps après le ciel fut entièrement couvert, et la fin de l'éclipse ne pouvait plus être observée. . . . .

Pendant l'éclipse totale je m'attachai à examiner la lumière de la couronne au moyen d'un petit polariscope d'Arago, que je tenais à la main. Tantôt je le dirigeai sur le centre de la couronne. Tantôt sur quelque point dans la couronne, ou même en dehors d'elle; mais de quelque manière que je tournasse mon instrument je n'aperçus aucune trace de colorisation sensible. La polarisation etait donc presque complètement détruite par les nuages qui se trouvaient devant le soleil.

Dr. D. G. Lindhagen.

42° 58′ 12″ N., 3° 53′ 15′ W. BEZANA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

Instrument.—Telescope by Merz, 83 millimeters aperture, and 1·18 metres focal length, with a power of 55. Field of view not taking in the whole sun. Polariscope.—A biquartz and a double-image prism.

Corona observed through clouds; in the first hasty

I repeatedly experimented with my polarizing apparatus during the expedition, and although I had never previously taken special pains to

improve my sense of colour by practice, yet I found it very sensitive. With polarized light, my apparatus showed four semicircular images, of which two and two were always complementarily coloured.

attempt no difference of colour could be detected. Afterwards Lindhagen fancied that faint differences between the images could just be perceived.

At the time of first contact the sky was tolerably clear, although a light vapour began to spread itself over the west and south—that is, over the part of the heavens to which our attention was directed. And as the time of the total obscuration drew near, the vapour gradually condensed into a thin film of cloud—which was, however, still perfectly transparent.

When I commenced my experiments with the polarizing apparatus, about a minute, as I imagine, had elapsed since the beginning of the total eclipse.

I had previously determined by observation of a surface of water the position of the plane of polarization for certain definite colours; and I now went with the apparatus over several points along the whole circumference of the corona, each time taking exact care that no two of the parts diametrically opposed to each other should be visible in the field of view of the apparatus at the same time.

In the first hasty attempt I could discover no difference of colour in the images in the polariscope; the light appeared to be everywhere pure white.

I set about these observations with the previous conviction that the light of the corona was polarized.

Although the circumstances on this occasion were not favourable, as I was well aware, yet it appeared to me that any, even ever so faint a trace of polarization, must have showed itself. I therefore renewed my observations, straining my eye in so doing as much as possible; and now I fancied that I could perceive, amongst other things, excessively faint differences between the images in the apparatus, but yet too feeble and therefore undefined to be able to ground any certain conclusion upon them. And it was not possible for me to fix this difference of colour sufficiently to determine directions of polarization.

Lastly, I directed the apparatus to some points of the corona in such a manner that only some of its most exterior rays were visible in the field of view; but if in the preceding experiment perhaps some faint traces of colour were perceptible, nothing of the kind was to be seen in this, although I kept my eye not less strained in this than in that.

From these observations no other conclusion can be deduced than that either the light of the corona is not polarized at all, or at least that only excessively faint traces of polarization are with difficulty to be perceived in it, unless the clouds, through which I observed the corona, introduced an element which essentially modified its polarization.

M. Antoine d'Abbadie. 42° 33'.3 N., 3° 20' W. BRIVIESCA, 18th July, 1860.

"Comptes Rendus," Vol. li., p. 705, pour séance du 12 Novembre, 1860.

Instrument.—Telescope $2\frac{7}{8}$ inches aperture and 31·5 inches focal length, with a power of 47 and a field of 45′. Polariscope, a quartz plate and a double-image prism of very small angle of separation.

The light of a protuberance observed, and no trace of polarization detected.

Comme j'avais inséré dans l'intérieur de ma lunette une plaque de quartz perpendiculaire à l'axe, je pus, entre la 5^e^ et la 6^e^ observation, comparer à deux reprises les couleurs des images d'une protubérance, après l'avoir doublée au moyen d'un prisme biréfringent. L'angle de ce prisme était tel que les deux images étaient presque exactement juxtaposées, et je ne pus discerner aucune trace de lumière polarisée dans cette protubérance. J'enregistre ce résultat avec d'autant plus de scrupule, que dans l'observation de l'éclipse de 1851 j'étais arrivé, en Norvège, à une conclusion contraire. Mais alors j'employais un prisme que j'ai encore et qui écartait beaucoup plus les images; il pouvait donc s'y mêler ainsi de la lumière de l'auréole qui, on le sait, est fortement polarisée.

M. Prazmowski. 42° 33'.3 N., 3° 20' W. BRIVIESCA, SPAIN, 18th July, 1860.

"Comptes Rendus" for Aug. 6th, 1860, Vol. li., pp. 195-7.

Instrument No. 1.—A telescope with an erecting eyepiece magnifying 22 times. A biquartz in the principal focus, and a Nicol's prism between the first and second lenses of the eyepiece.

Instrument No. 2.—A telescope with an erecting eyepiece magnifying 44 times. A plate of quartz cut perpendicular to the axis placed between the first and second lenses of the eyepiece, and a double-image prism of small angle (viz. 1′.5) between the eyepiece and the eye of the observer.

Pour déterminer la direction du plan de polarisation de l'auréole, j'ai fait usage d'une lunette à oculaire terrestre grossissant 22 fois. Au foyer commun de l'objectif et de l'oculaire, j'ai disposé une plaque de quartz à double rotation, donnant la teinte sensible. Un prisme de Nicol était placé entre le premier et le second verre de l'oculaire, là où le pinceau est le plus aminci. L'addition de ce polariscope ne modifiait en rien la netteté des images de ma lunette.

Description of instrument.

1. With the first instrument and the line of junction vertical and bisecting the dark moon, the two segments of the corona were observed to be *not* of one uniform colour throughout, but red and red above the moon near to the line of junction and green and green below. 2. The line of junction was made to revolve, always bisecting the dark moon. The colours we observed to revolve with it. 3. The colours were very vivid—they were observed to be most intense at a certain distance from the moon's limb. 4. With the second instrument the two images of the prominences were observed to be of the same colour and intensity.

Comme dans le polariscope d'Arago, le champ de la lunette se trouvait partagé, par une ligne noire, en deux segments colorés. Le prisme et la plaque étaient solidaires, et tournaient ensemble de telle sorte que les deux moitiés du champ n'étaient uniformément colorées que dans une seule position : celle où la ligne de séparation coïncidait avec le plan de polarisation de la lumière.

Au moment de l'obscurité totale, l'auréole est apparue ; j'ai amené l'image de la Lune au centre du champ de la lunette, la ligne de jonction des deux quartz étant verticale, et coupant l'image du disque et de la couronne en deux parties égales. Les deux segments de l'auréole ne se sont pas montrés également colorés dans toute leur étendue. Les extrémités supérieures et inférieures de chaque segment, en contact avec la ligne de jonction des quartz, étaient seules uniformément colorées ; à droite et à gauche de ces extrémités, les deux moitiés étaient vivement colorées de teintes complémentaires, l'une rouge, l'autre verte.

First observation.

Un mouvement de rotation imprimé à l'oculaire autour de son axe n'a rien changé à ces colorations par rapport à la ligne de séparation des quartz. La lumière de la couronne était donc polarisée, et son plan de polarisation coïncidait avec la normale au contour de la Lune.

Second observation.

Ce n'étaient pas des traces de polarisation, mais les couleurs les plus intenses : d'un côté, le rubis le plus vif, de l'autre l'émeraude la plus pure. Autant que je me rappelle, la partie de l'auréole la plus fortement colorée ne correspondait pas à la partie la plus lumineuse, mais se trouvait à une certaine distance du bord de la Lune.

Polarization very intense.

Une seconde lunette, semblable à la précédente, mais d'une grossissement double, était destinée à l'observation des protubérances. Dans l'oculaire de cette lunette, entre le premier et le second verre, j'avais placé une lame de quartz perpendiculaire à simple rotation donnant le rouge ; en avant de l'oculaire se trouvait un prisme biréfringent d'un angle

Description of instrument No. 2.

assez faible, et donnant aux deux images une séparation angulaire de $1\frac{1}{2}$ minute. Ce prisme pouvait tourner sur lui-même.

Dans cette disposition, la Lune et la couronne étaient bien dédoublées par le prisme, mais d'une si petite quantité, que la majeure partie de leur étendue se trouvait formée par deux images complémentaires reconstituant la lumière blanche. Les protubérances se trouvaient également dédoublées; mais comme leur étendue était moindre que 1.5′, écartement donné par le prisme, il en résultait que les deux images n'étaient pas superposées, mais nettement séparées. Je voyais donc deux images des proéminences se projetant sur le fond blanc de la couronne.

Third observation.

Si les protubérances eussent été polarisées, les deux images eussent été colorées de teintes complémentaires; or ces deux images étaient bien certainement de même teinte et de même intensité lumineuse. Je crois donc pouvoir avancer que la lumière des protubérances n'est pas polarisée.

Mr. J. Beck.

42° 42′ N. } NEAR MIRANDA, SPAIN,
2° 59′ W. } 18th July, 1860.

MS. Eclipse Reports, Himalaya Expedition, 1860.

Instrument.—Telescope of $3\frac{1}{2}$ inches' aperture, and a power of about 60 diameters.

I placed a glass (upon which were formed circular crystals of salacine) in the focus of the top lens of the eyepiece.

Over the eyepiece I placed a tourmaline of blue tint, part of one known amongst microscopists as Woodward's tourmaline, and noted for its excellence in not affecting the natural colours given by polarized light. I used only direct vision.

Polarization springing up with totality very strong on corona, faint on dark moon.

During the eclipse, before totality, I carefully examined the disc of the moon for polarized light, throwing the cusp of the sun in and out of the field, but could not detect any. I also examined the sun itself with a like result; but the instant the corona showed itself, the field of my telescope was full of polarized light.* I observed its existence on the disc of the moon, but much more strongly on the corona, and surpassing in brilliancy that seen at about 90° from the sun.

* Mr. Beck remarks that "the amount of polarization was so great that he could only account for it by attributing it to the self-polarized light of the corona."

Herr Barth.

42° 50′ 41″ N.
2° 40′ 20″ W. } VITORIA, 18th July, 1860.

"Über Totale Sonnenfinsternisse," Dr. von Mädler, Jena, 1816 (p. 18).

Instrument—Not described.

Die Beobachtungen des Herrn Barth, der sich nur mit Polarisationsversuchen beschäfigte, stimmen im Resultat mit denen des Herrn v. Rennenkampff überein. Results the same as those of Herr von Rennenkampff.

Herr G. von Rennenkampff.

42° 50′ 41″ N.
2° 40′ 20″ W. } VITORIA, 18th July, 1860.

"Über Totale Sonnenfinsternisse," Dr. von Mädler, Jena, 1861 (p. 17).

Instrument.—A polariscope, consisting of two tourmalines, one red and the other green, with a thick plate of Iceland spar between.*

Ein Polarisations apparat von zwei Turmalinplatten, eine roth, die andre grün, und einer zwischen beide geschobenen dicken Platte von isländischem Bergkrystall zeigte keine Spur von Polarisation im Lichte der Corona. No polarizaton detected.

M. Barreda.

40° 5′ N.
0° 0′ long. } DESIERTO DE LAS PALMAS, 18th July, 1860.

"Über Totale Sonnenfinsternisse," Dr. von Mädler, p. 28.

Instrument.—Not described.

Während einiger freien Momente untersuchte Hr. BARREDA das Licht der Krone und fand es sehr stark polarisirt. During some spare moments Barreda investigated the light of the corona and found it strongly polarized.

* If the above is a correct description of the instrument made use of by Herr von Rennenkampff, it is not surprising that he was unable to detect any traces of polarization in the light of the corona. Under no circumstances would either fringes or colours be seen with such a combination. With a tourmaline in front of the Iceland spar the only indication of polarization that he could possibly perceive would be that certain parts of the corona, if radially polarized, would be brighter than others, and their intensity would change on revolving the instrument. But in no case would such a combination be as effective as an ordinary Nicol's prism.

Padre Secchi. 40° 5′ N. 0° 0′ long. DESIERTO DE LAS PALMAS, 18th July, 1860.

"Relazione delle Osservazione," etc.: P. Secchi, Rome, 1860.

Instrument.—An Arago polariscope apparently used with the naked eye.

The extremities of the rays of the corona were not of the same tint in the two images. The central parts, however, were white in both images.

(p. 16.) Per accertare la natura de' raggi della corona posi l'occhio ad un polariscopio di Arago, e vidi sicuramente che le estremitá loro non erano della stessa tinta nelle due immagini, restando però in ambedue vivo il bianco delle parte centrale: nelle due immagini la corona me parve allungata in due direzioni perpendicolari.

Dr. Souza.
Señor Brito Capello. 40° 7′ N. 0° 6′ E. OROPESA, 18th July, 1860.

"Memoria sobre el Eclipse de Sol," por D. Francisco de Paula Marquez, p. 23.

Instruments.—Dr. Souza an Arago polariscôpe; Señor Capello a Savart polariscope. (Query used without a telescope.)

From the moment that the corona appeared, Souza examined it in all directions with an Arago polariscope, but found no trace of polarization. But subsequently Capello, with a Savart, found the light of the corona polarized.

El doctor SOUZA, desde el momento en que se presentó la corona la exploró en todos sentidos con un polariscopo bilunar de Arago, y no halló la menor señal de polarizacion: pero más tarde, cuando ya se habian presentado las protuberancias, el señor BRITO CAPELLO, con un polariscopo de Savart, halló polarizada la luz de la corona.

Lieutenant Campbell. 1½ mile W. by S. of JAMKANDI, 18th Aug., 1868.

"Proceedings of the Royal Society," Vol. xvii., pp. 120 124.

Instrument.—A telescope of three inches' aperture—on a rough altitude and azimuth mounting—with polariscopes. No. 1. A double-image prism with quartz plate.* No. 2. An ordinary Savart.

Description of instrument. Clouds during totality. With double-image prism corona found to be polarized, but could

(p. 120.) The telescope was provided with three eyepieces of magnifying powers 27, 41, and 98; and with it were furnished two analysers for polarized light: viz., a double-image prism, and a "Savart's polariscope." The first gives two images of the object viewed, which, when polarized

* This information is obtained from Mr. Ladd, who made the instrument.

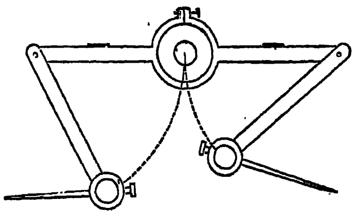
not detect polarization in the great protuberance. With Savart radial bands distinct but not bright, which travelled along the limb when the polariscope was turned in its cell. With smaller field bands seen as tangential.

light is present, become strongly coloured with complementary tints, by whose changes, according to the position in azimuth of the analyser, the plane of polarization may be found.

The second shows the presence of polarized light by the formation across the image of the object viewed of coloured bands, which alter in arrangement and intensity according to the position of the polariscope with reference to the plane of polarization, and hence afford a means of arriving at a knowledge of the latter.

With the former, slight polarization would probably be more readily recognized at a glance; while with the latter the plane of polarization could be more easily and accurately determined.

To carry these instruments I had a pair of jointed arms constructed, so attached by a collar and screw to the eye-tube as to admit of the eye-piece being changed. Each arm carried one of the analysers in a cell, in which a rotatory motion could be given for analysing purposes. The annexed rough sketch (made from memory) will help to give an idea of the contrivance. Either analyser could be brought instantly into position before the eyepiece of the telescope, or both could be turned aside and the telescope used by itself at pleasure.



Immediately behind the apparatus a circular piece of cardboard of about twelve inches' diameter and neatly adjusted, was firmly attached to the eye-tube, and to each analyser was affixed a long pointer, by which its azimuth could be referred to the graduations on the card circle, should measures of position or change of azimuth appear desirable.

Much cloud during totality.

(p. 122.) Three to five seconds before totality a thick cloud shut out everything, and the rest of the phenomena were only seen fitfully through openings in the cloud, for an aggregate period which I estimate at somewhat less than half that of totality.

This alternate appearance and disappearance troubled me greatly, and gave rise to nervousness and excitement; for, owing to the imperfect mounting of my telescope, I was apt to lose my place whenever the light was cut off by clouds, and to waste the precious moments of clearness in finding it again.

Observation with double-image prism.

On the first opportunity after the commencement of the eclipse I turned on the double-image prism, with the eyepiece of 27 magnifying-power, as recommended in the instructions, which gave a field of about 45′ diameter. A most decided difference of colour was at once apparent between the two images of the corona. But I could not make certain of any such difference in the case of are markable horn-like protuberance, of a bright red colour, situated about 210° from the vertex, reckoned (as I have done in all cases) with reference to the actual not the inverted image, and with direct motion. I then removed the double-image prism and applied the Savart's polariscope, which gave bands at right-angles to a tangent to the limb, distinct, but not bright, and with little if any appearance of colour. On turning the polariscope in its cell, the bands, instead of appearing to revolve on their own centre, passed through various phases of brightness, arrangement, etc., travelling bodily along the limb,* always at right-angles thereto, but without much change in intensity, or any at all in arrangement.

Observation with Savart.

The point at which they seemed strongest was about 140° from the vertex, and I recorded them as black-centred.

Observation with higher power and smaller field.

Believing that with a higher power and a smaller field I should find it easier to fix my attention on one point of the corona, and observe the phases of the bands at that point, I changed eyepieces, applying that of 41 power. With this eyepiece the first clear instant showed the bands much brighter than before, coloured, and as tangents to the limb at a point

* With radial polarization, and a field whose diameter is less than the breadth of the whole group of bands, the coloured fringes will be most intense at those parts of the field where the plane of polarization is either parallel or perpendicular to the direction of the bands, and the fringes will be altogether wanting at those portions of the field where the plane of polarization makes an angle of 45° with the principal plane of the Nicol. On turning the Savart the direction of the bands would revolve with the instrument, while the area of their maximum intensity would pass from place to place along the limb, giving to the bands the appearance of sliding or moving along the limb. If the whole corona were within the field, and the group of Savart's bands were sufficiently broad, there would be four areas of maximum intensity—two in which the bands would appear as tangents to the limb, and two where they would be perpendicular. The breadth of the bands depends upon the thickness of the quartz plates of the Savart; and if the power of the telescope were such that the apparent semi-diameter of the moon was greater than the breadth of the whole group of bands, then it is evident that the fringes would be seen as either perpendicular or tangential to the moon's limb as the centre of the field of the Savart was moved over the image of the corona.

about 200° from the vertex: but before I could determine any further a cloud shut out the view, and a few seconds later a sudden rush of light told me that the totality was over, though it was difficult to believe that five minutes had flown by since its commencement.

I experienced a strong feeling of disappointment and want of success; the only points on which I can speak with confidence being as follows:—

(1) When using the double-image prism, the strong difference of colour of the two images of the corona, and the absence of such difference in the case of the most prominent red flame. Summary.

(2) With the Savart's polariscope the bands from the corona were decided; with a low power they were wanting in intensity and colour—excepting alternate black and white—making it difficult to specify the nature of the centre; and their position was at right-angles to the limb, extending over about 30° of the circumference. When the polariscope was turned, the bands travelled bodily round the limb without other change in position or arrangement, as if indeed revolving round the centre of the sun as an axis.

With a higher power, when a smaller portion of the corona was embraced, the bands were brighter, coloured, and seen in a different position—viz., tangents to the limb.

The appearance observed with a low power seems exactly what might be expected, supposing the bands to be brightest at every point when at right-angles to the limb; in which case the bands growing into brightness at each succeeding point of the limb would distract attention from those fading away at the points passed over as the analyser revolved.

Capt. Branfill. 16° 17′ 29″ N. / 80° 27′ 9″ E. } GUNTOOR, 18th Aug., 1868.

"Memoirs of the R. A. S.," Vol. xxxvii., pt. 1.

Instrument.—3¾-inch telescope with polariscope, consisting of the plates of a Savart used with a Nicol's prism and double-image prism. (Query.)

(p. 21.) The instrument * used by Captain Branfill for these observations was 3¾ inches in aperture and 5 feet in focal length: it was, indeed, one of the old collimators of the Greenwich Transit Circle. Description of instrument. Savart's bands not visible on great horn-like protuberance.

* The description of the instrument is by Col. Tennant.

although they were visible on the background of corona. Brightest portion of the corona clearly polarized in a plane passing through the sun's centre.

(p. 22.) The polariscope eyepiece was made by Mr. Ladd for a smaller telescope which had been lent to me by the Astronomer Royal, and was adapted by Mr. Simms to the 5-foot, with which it had a magnifying power of about 30. It was of Ramsden's construction, having a positive focus, and was contained inside an outer jacket, into which it slipped till a wire came into focus; close to this wire was an opening in the jacket through which perforated plates (similar to the Waterhouse diaphragms of photographic lenses) could be inserted, in order to limit the field of view. Inclosing the whole eyepiece and passing beyond it, the jacket carried at the eye end a small piece of tube, into which fitted two cells carrying the prisms. Between these prisms and the lens nearest to it, there traversed backwards and forwards a right-angled prism of ebony, having in it two holes—one plain, the other carrying the compound quartz plate of a Savart's polariscope. In one of the prism cells is a Nicol's prism, in the other a double-image prism and quartz plate. With the jacket everything turned in an adapter carrying an index, and there were rough graduations on the jacket to enable the position of the wire to be known. There were thus four combinations of the slide and prisms which could be rapidly changed one for another, and which showed the existence of polarized light by different phenomena.

Observation of protuberance.

(p. 25.) [Captain Branfill says,] "Immediately after the commencement of totality my attention was caught by a tall, narrow, brilliantly lighted, rose-coloured, horn-like protuberance. With the Nicol and crossed quartz in, and the largest shifting diaphragm, I turned the centre of the small field" ($8\frac{1}{4}'$ diameter). "On this I received a very vivid impression of the beautifully clear features and colour of this protuberance. The background gave Savart's bands, but the horn did not.

Observation of brightest part of the corona.

"With the finder I then sought the brightest part of the corona, and directed the instrument upon it (viz., the left upper quarter), when the first-mentioned group of protuberances was just disappearing." (The photographs show that this was about two minutes after the disappearance of the sun.) "This also was near where the line of dark spots had disappeared. I found this part clearly polarized in a plane passing through the sun's centre. I determined the position by a reading of the graduated arc on the eyepiece tube, taken when a wire in the eyepiece was a tangent to the moon's limb at the spot."

[Col. Tennant says,] "I find the following statements in other parts of Capt. Branfill's notes: 'Bright white centre band at 119°. Bands disappeared at 180° and 92°. Wire a tangent to the moon's limb at 52°.' The plane of polarization would thus have been at 136°,* and the radius of the moon at 142°. I find from a projection that the position of this point of the moon's limb at the sun's centre would have been 141° two minutes after the sun's disappearance, and it would have been less earlier. When the central band disappeared, faint bands were seen on the edge of the field right and left; it appeared as if no plane could be found in which there was an entire absence of bands. The white centre band was clearly marked when the wire was perpendicular to the sun's [moon's?] limb, and as clearly disappeared when turned about 45° each way. The bands appeared on the moon's disc very faintly. **Light from moon's disc examined.**

"The last phenomenon I did not understand, and at first it struck me that it might be from the interposed cloud; but Capt. Branfill could give no information as to the centre band. He had not noticed the change from white to black, but the bands were very faint. I have since found that the eyepiece even shows the fringes carried over the edge of the limiting diaphragm—owing, I presume, to dispersed light; and of course they would be similarly seen to cross the dark disc of the moon."

[Capt. Branfill says,] "The double-image prism with two diaphragms gave the same result: plentiful polarization in the plane passing through the sun's centre. . . . When quite satisfied as to the polarized light in the corona, and its plane 'of polarization,' by repeated examination in various places, I gave all my attention to the horn-like protuberance, which was still clear and high. I used the smallest diaphragm, and the Nicol with and without the crossed quartz: and also the double image with the largest diaphragm; but could not detect any trace of polarized light in it, any bands, or any changes of colour or relative brilliancy. . . I was still examining the same protuberance, and about to try the simple Nicol again, when the sun reappeared (much before the time I thought), and put a stop to the observations; for, on putting on a dark glass, I lost sight of the prominences and all traces of polarized light." **Further observations.**

* The plane of the wire was nearly in the meridian when the index read 0°.

Mr. G. K. Winter. 16° 11′ 33″ N. 81° 12′ 15″ E. } MASULIPATAM, 18th August, 1868.

Report of the Government Astronomer upon the proceedings of the Observatory in connection with the Total Eclipse of the Sun on August 18th, 1868.

Instrument (page 19).—Telescope $2\frac{1}{2}$ inches aperture and 28 inches focal length, with a negative eyepiece adapted to be used with either a Savart's polariscope* or a double-image prism. The Savart's polariscope only was, however, employed, and as its quartz prism could not be removed without some little difficulty, I was unable to use it as a plane Nicol's prism. It had an index corresponding with the direction of the bands to determine the plane of polarization. The telescope was fixed upon a small equatorial mounting.

Strong radial polarization.

(p. 21). After about two minutes' observations with the erect eyepiece,† the negative eyepiece and the Savart's polariscope were used. The corona was very strongly polarized in a plane passing through the centre of the sun; the bands were extremely vivid—more so than any I have observed in a clear sky. I tried several portions of the corona, and in all the white central band was brightest when it corresponded with the sun's radius, and the black band was equally marked when the bands were tangential to the limb. There was not sufficient time fairly to test the red flames for polarization.

* At page 11 Mr. Pogson says:—"Mr. Huggins also sent out, at my request, a set of polarization prisms, by Mr. Ladd of London, similar to those supplied to Major Tennant and Lieut. Herschel by the Royal Astronomical and Royal Societies; the use of these was the special task undertaken by Mr. Winter, and so completely and successfully was it accomplished, that the like investigation need not again be attempted."

Mr. Ladd informs us that the negative eyepieces were fitted with diaphragms with a slit suitable for the double-image prism, and a small circular hole to use with a Savart. He believes that the circular hole was so small that it must have restricted the field of view to certainly less than half a solar diameter. On this supposition the polarization observed by Mr. Winter in each case corresponded with an isolated portion of the corona, and we need not inquire whether he directed his attention to the centre of his field of view.

† The erect eyepiece was not fitted with a polariscope.

MM. Latourneur et Béhic. 11° 42′ 35″.0 N. 99° 47′ 45″ E. } WHA-TONNE, SIAM, 18th August, 1868.

"Rapport sur l'observation de l'Eclipse de Soleil du 18 Août, 1868," par M. Stephan: Paris, 1869, p. 30.

Instrument (page 17).—MM. Letourneur et Béhic, munis, le premier, d'un polariscope de Savart, le deuxième, d'un polariscope d'Arago.

(page 30.) La polariscopie ne donna que des résultats négatifs, nous sommes bien loin d'en conclure qu'il n'y a rien à trouver en ce sens; mais alors il faudra opérer d'une autre manière. No results.

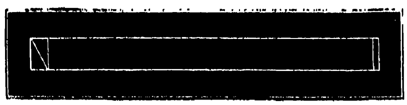
Prof. E. C. Pickering.* 40° 57′ N. 91° 38′ W. } MOUNT PLEASANT, IOWA, 9th Aug., 1869.

"The Journal of the Franklin Institute," Vol. lxxxviii., pp. 285 and 372.

Instrument.—A tube 20 inches long, closed, with a double-image prism at the eye end and a plate of quartz at the other.

The two images of the corona appeared precisely alike: both pure white; the one upon a uniform blue background, the other on a uniform yellow background.

The form of polariscope used was that adopted by Arago in his experiments on sky polarization. It consists of a tube about 20 inches long, and 2 inches in diameter, one end of which is closed by a double-image prism of Iceland spar, [giving a separation of nearly 3°,] and the other by a plate of quartz. Looking through



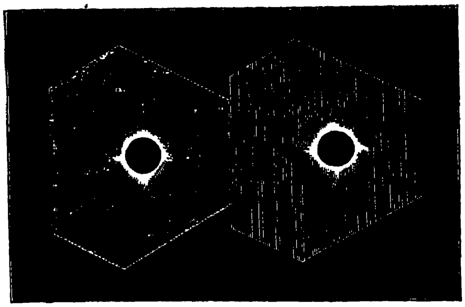
the former, we see two images of the latter, which, when the light is polarized, assume complementary tints. If now the corona was polarized in planes passing through the centre of the sun (as is generally admitted), when viewed through the polariscope, in one image the upper and lower

* Besides polariscopic observations, Professor Pickering made spectroscopic as well as general observations with a telescope during totality. He cannot, therefore, have been able to devote much time to a careful examination of the colours on different parts of the corona. When we consider the smallness of the unmagnified images, and the fact that the series of polarization colours would recur twice in passing round the corona, and that each colour would therefore extend over a very small area, it is perhaps not to be wondered at that he failed to notice the difference between the images.

parts should have appeared blue and those on the right and left yellow; while in the second image these colours would be reversed—the yellow being above and below, and the blue on the sides.

Observation.

In reality the two images were precisely alike, and both pure white—but one was on a blue, the other on a yellow background. From this we infer that the corona was unpolarized, or at least that the polarization was too slight to be perceptible.



(p. 372.) The images represented the appearance shown in the figure. The hexagons represent in form and size the plate of quartz; the black circles the moon, here drawn a sixth of an inch in diameter, as the scale is about 3° to the inch.

(p. 286.) The coloured background mentioned above shows that the sky, close to the corona, is strongly polarized; and since the tint is uniform on all sides of the sun, the plane of polarization is independent of the position of the latter—that is, the same on all the sides that it is above or below it. The most probable explanation of this most unexpected result is that the earth beyond the limits of the shadow, being strongly illuminated, acts as an independent source of light, and this being reflected by the air, becomes polarized in planes perpendicular to the horizon.

Mr. Moulton. 36° 40′ N. 6° 23′ W. } SAN LUCAR, SPAIN, 22nd Dec., 1870.

MS. Reports of the 1870 Epedition.

Instrument.—Telescope, 3-inch object glass, field of view about 40′. Polariscope.—A Babinet's compensator, angle of wedges 2° 40′, fixed to and revolving with a positive eyepiece, among the lenses of which was packed a Nicol's prism.

Corona seen through clouds; no polarization detected.

My instrument was a very inferior one, reflexion from the inside of the tube being so imperfectly destroyed that the spurious bands could only be avoided by using a long nozzle lined with black velvet. Even then

traces of polarization in the extreme portions of the field could not be relied on.

The sky was covered with a haze during the whole of the eclipse, through which, however, the sun could be distinctly seen up to the time of totality, excepting during a few minutes when drifting clouds obscured it. At the commencement of totality the haze alone hindered our view, but almost immediately the obscuration was increased by the edge of a drifting cloud, which, however, did not prevent the corona from being visible. Soon after totality, rain commenced to fall, and the increasing thickness of the clouds rendered the sun invisible during the remainder of the eclipse.

I commenced observing the sun through a dark glass some five minutes before totality. The thin line of light remained visible till it broke up into a discontinuous line of small bits of light, and then all was dark.

I found no trace of bands on the corona. I first examined it near to the point of disappearance of the sun, and rotated my analyser through a right angle, keeping the same portion of the corona in the middle of the field, but with no effect.

I subsequently repeated the experiment on a portion of the upper part of the corona, but with the same result. I also found no polarization on the dark disc, or on the clouds at a little distance from the moon outside the corona.

At the time I came to the conclusion that the thickness of the clouds was not sufficient to account for this, on the supposition that the light of the corona is polarized in varying directions, since the corona was distinctly visible through them; but I have since inclined to the belief that I underrated the amount of dispersed corona light which the clouds through which I was looking would give off. This cause of error is independent of the direct effect of the clouds in polarizing the light that passed through them.

Previous experiments had shown me that if the clouds are thin, the polarization produced by them is very marked, but that thicker clouds produce but little effect—probably through the great irregularity of their structure. The clouds in question were of such a nature during the time I was observing the corona through them that I should not have expected them to have produced polarization in common light had they been interposed in its path. I was unable to see the corona after totality.

Mr. C. Becker. 36° 38′ N. 6° 12′ W. MARIA LOUISA OBSERVATORY, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition. See also "Monthly Notices," Vol. xxxi., pp. 56—60.

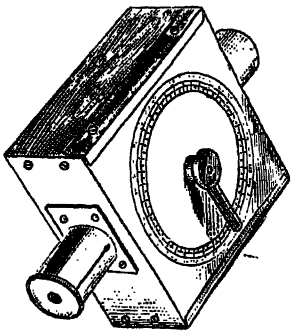
Instrument.—A polarimeter, used without a telescope.

Description of instrument.

Strong polarization sprang up with totality; bands all across the field, which disappeared when turned at an angle of 23° to the vertical.

In order not to lose any light, I dispensed, by the advice of Professor Pickering, with a telescope, and made use of a polarimeter upon the unmagnified image of the corona.

My field of view was bounded by the edges of a $\frac{3}{4}$-inch tube at a distance of about 9 inches from the eye, and was therefore nearly 5° in diameter. The polarimeter consisted of an ordinary Savart's polariscope, in front of which was a box containing four plates of crown glass packed in a frame, so that they could be turned about an axis at right-angles to the axis of the Savart,* and the position of the plates could be read on a graduated scale at the side of the box.



The plates of the Savart used by me were of such a thickness that the whole group of bands appeared to occupy about half the breadth of the field. Roughly speaking, the breadth of the individual bands at the centre of the field was about one-fourth of a degree, and the breadth of the whole group two-and-a-half degrees. The Savart was fixed to the box containing the revolving plates, so that the bands were seen as parallel to its longest edge and perpendicular to the axis about which the plates revolved. My method of determining the position of the bands was to measure the inclination of the edge of the box to the horizon by means of a clinometer, consisting of a graduated arc of cardboard and plumb-line.

The polarimeter was fixed on a stand, so that it could be directed to the sun, leaving both hands of the observer free.

Observation.

No trace of polarization was observed before the commencement of totality, but immediately upon the disappearance of the sun the bands in the Savart came out very strongly, and were seen *right across*† the field,

* See the figure given to illustrate Mr. Griffith's instrument (p. 318).

† See the remarks (p. 259) on Mr. Lockyer's similar observation with a Savart.

apparently not interrupted by the dark moon or corona. When the instrument was turned round, so that it made an angle of 23° with the vertical, the bands disappeared.

Prof. S. P. Langley. 36° 43′ 56″ N. 6° 10′ 8″ W. JEREZ, 22nd Dec., 1870.

United States Coast Survey Report for 1870, Appendix No. 16.

Instrument.—A Savart's polariscope attached to small telescope with an eyepiece giving a field of about 2°.

Description of instrument. Observation made through slight haze. Strong radial polarization traced to a distance of 40′ from the lunar limb. Bands observed to decrease in intensity near to the moon's limb. No bands detected on the moon's disc.

(p. 46.) Of the coloured bands in the particular instrument employed, ten or twelve are distinctly seen, each being over one degree in width; so that when the little instrument is directed to the moon, its disc is more than covered by one of them, and the corona cannot well cover two of the bands at once.

It is desirable, however, that several of the bands should be seen projected on the source of light, and accordingly the polariscope was adjusted to the finder of the telescope already referred to, and the magnifying power (linear) being about twelve times, the image of the moon was now found to cover four of the bands with their intervening spaces. No sensible polarization was caused by the glasses of the finder.

(p. 48.) After some thirty seconds of intent but fruitless scrutiny, I turned to the polariscope. The haze at this time was very slight indeed, and at one moment the sky to the naked eye was distinctly blue.

Observation.

On looking into the Savart, the field, which a few minutes before was vacant of bands, was now traversed by them—vertically disposed, of course (since it was still in its normal position), but surprisingly distinct for the light, even their colour being visible. They ended before reaching the edges of the field, which embraced about two degrees, and did not appear to be traceable up to the disc. I now commenced turning the little instrument; moving the notch which marked the vertex towards the right. I had tried to bring to this observation a mind free from the bias of any preconceived opinion; yet, as I am since conscious, I turned it under a certain prepossession that the polarization would prove to be in a

plane either vertical or horizontal—in either of which cases the bands would vanish at an angle of 45°. When this point was reached, they were as vivid as before. I paused to assure myself of the fact (looking at and feeling the mark on the circle), and then slowly continued the rotation till it had been carried through 180°. In all angles the band normal to the limb was the best marked, but all the bands remained distinct enough to show colour in any position. Their extent from the sun I cannot give; yet, as they were not distinguished with certainty at the edges of a field 2° in diameter, I should rudely estimate their average extent at 40′. I could not, as I say, follow them up to the moon's limb, and their increasing faintness as they approached it was noticed. I did not see any bands on the moon, but my attention was directed so exclusively to verifying their persistence around it, that little weight should attach to this negative evidence.

When the polariscope had been turned through half a revolution, it had rendered all the evidence to be obtained from it; but for greater security the rotation was continued through nearly 180° more. There was no other result. There were no maxima or minima of intensity corresponding to one position angle more than another.

[The following account of Prof. Langley's observations was published shortly after the eclipse in "Nature," Vol. iii., pp. 228-9.]

Description of instrument.

"I used a Savart's polariscope, attached to a small telescope of 1½ inches aperture, and having a field of about 2°. The observations with the Savart's polariscope being subject to ready misconception, the preparation for observation, and the appearance during it, are here given with some minuteness.

"Before the eclipse the Savart was so adjusted that the bands were most distinct when vertical, viewing the meridian sun reflected from water. None were visible when the sun was directly scrutinised, before or after totality.

Observations.

"During totality the appearance which presented itself was unexpected. The bands were distinctly seen on the corona, and were brightest where normal to the limb and where tangential to it. As the polariscope was slowly rotated, no marked diminution of their brightness was seen, and when it had been turned through 45° they were as bright as before, distinctly visible even in colour; and they so remained, the rotation being continued for greater security through a whole revolution. During the

whole time they presented the appearance described, characteristic of radial polarization. They were not noticed on the disc of the moon; but this may well have been from the observer's attention being so exclusively directed to verifying their persistency on the corona.

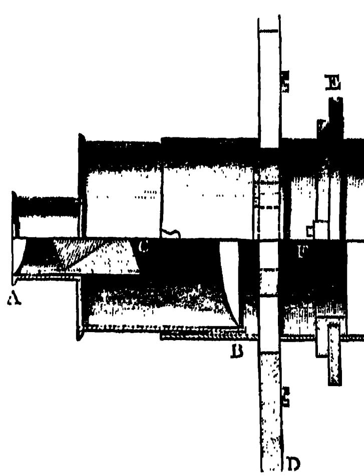
Prof. E. C. Pickering. 36° 43′ 56″ N. 6° 10′ 8″ W. } JEREZ, 22nd Dec., 1870.

Coast Survey Report for 1870, Appendix No. 16.

Instruments.—1. Plate of selenite and double-image prism; naked eye observation. 2. Biquartz and Nicol used with telescope. 3. Savart; naked eye observation.

With double-image prism and selenite, distinct colours on corona showing radial polarization, and comparatively faint sky polarization. With biquartz, corona seen through clouds; distinct though faint colours detected on corona, showing radial polarization and plane polarization on moon's disc. With Savart, bands seen on sky much stronger on corona; when turned, they disappeared on sky, but remained on corona.

(p. 57.) The telescope I used was the finder of the 15-inch equatorial at Cambridge. Its aperture was 3 inches, focal length 48 inches, and its mounting equatorial. I had attached to it the eyepiece represented in the figure, made by Zentmayer of Philadelphia.



A B is a common positive eyepiece containing a Nicol prism C. At its focus is a slide D, with three holes, into which different polarizing plates can be placed and changed instantly. A B can also be drawn out, and a higher or lower power substituted. The whole was arranged so that it could revolve, and the angle be measured by a graduated circle E and index F. One of the apertures in D was left vacant, so that the Nicol prism alone could be used; it would perhaps be better to fill it with a thick piece of plate-glass, that the focus might be the same as when the other apertures were used. The second plate contained a biquartz, or two plates side by side—one turning the ray to the right, the other to the left. When this line of junction is parallel to the plane of polarization, both assume the same colour, which is a peculiar violet tint, known as the transition or sensitive tint. Turning it 90°, the colour of both becomes

complementary or dull yellow; in other positions, one is red, the other green. In the third aperture, at the suggestion of Professor STOKES, I placed the quartz wedges used by Babinet, which show bands like those of a Savart polariscope, only reversed—that is, strongest when inclined 45° to the plane of polarization, and disappearing when parallel or perpendicular to it. I at first intended to use a Savart in this position, but this requires parallel rays, and cannot be used with a diverging beam. I also had a cheap 3-inch telescope, by Newton, for a collimator in testing the polariscopes and for determining contacts and general observations. It was suggested by Professor YOUNG that one cause of my not seeing any polarization in 1869 may have been the small size of the corona. He therefore proposed that it should be enlarged by placing an Arago in front of the telescope. I accordingly strapped a small French telescope as a finder to my larger one, and slipped a cap on the objective with a double-image prism and quartz plate. This arrangement has also the much more important advantage of eliminating the sky polarization; for while the two images of the corona are so far separated that one only is visible, the second image of the sky, distant two or three degrees, overlaps the first, so that all disturbing effect of it is removed, and we have the corona polarization alone.

To measure the degree of polarization, a modification of Arago's polarimeter * was used, consisting of four plates of glass free to turn, and carrying an index and graduated circle which shows the amount of the rotation. The object to be tested is viewed through them with a Savart polariscope, the bands being placed parallel to the axis of rotation. The whole instrument is turned until the bands are perpendicular to the plane of polarization, when they will be white-centred, and the plates are then turned until they disappear. From the angle we can tell the amount of polarization present, since it is then just equal to that produced by the plates. We also carried two Arago's polariscopes, one consisting of a double-image prism and *quartz* plate placed at opposite ends of a tube of such a length as to give two images of the quartz in contact, but not overlapping. The second Arago consisted of a double-image prism

* See the woodcuts given on p. 294 and p. 318. The polarimeters used by Mr. Becker, Prof. Pickering, and Mr. Griffith, were all made on one pattern; the form was suggested by Prof. Pickering.

and plate of selenite placed close together, and attached to the end of a tube, the further end of which was closed by a cap with a square hole in it.

Observation with double-image prism and selenite. Horizontally and vertically polarized fields seen side by side.

(p. 59.) I first used the smaller Arago with a plate of selenite, which gave red and green images; but since it is impossible to grind selenite to as true a surface as quartz or glass, objects seen through it are a little indistinct, as when seen through mica or uneven window-glass. I found, however, the two images of the corona

distinctly coloured, the right-hand one red above and below, and green on each side; the other with these colours reversed, showing a radial polarization; the sky polarization was comparatively faint. I next pulled the prism and selenite, which were fastened together, out of the tube, and repeated the observation; the sky polarization was thus eliminated, as two images distant 3° were superimposed. The same result was obtained as before—showing that the effect could not be due to sky polarization.

Horizontally and vertically polarized fields superimposed.

Observation with biquartz.

I then returned to my telescope, in which I had adjusted my biquartz and the low-power eyepiece. With this I got these conclusive results. The image was dimmed by the clouds, though not sufficiently to prevent the colours from being distinctly visible. On attempting to record them, however, they seemed to be continually changing; and this was probably in reality the case, as we know that a clear sky is strongly polarized, while, when cloudy, no signs of this phenomenon can be detected. Hence, every cloud crossing the moon's disc would change the colours. I then attempted to see if at any time I could detect the colours due to radial polarization—that is, green above and red below—and am very confident that at one time these colours were present. The colours were distinctly, though faintly, visible over the moon's disc, and uniform on each side of the line of junction of the quartz, showing that the moon's disc was polarized not radially, but in the same plane throughout. These observations took some time, and when completed I looked at the corona with a Savart not attached to a telescope. This showed bands on the sky which were much stronger on the corona, and when turned so as to disappear on the former, still remained visible on the latter—thus showing the independent polarization of the latter. Totality being now nearly over, I watched for the passage of the shadow.

Observation with Savart, naked eye.

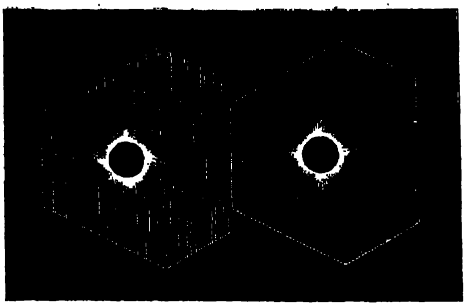
Mr. W. O. Ross. 36° 43′ 56″ N. 6° 10′ 8″ W. JEREZ, 22nd Dec., 1870.

Coast Survey Report for 1870, Appendix No. 16, p. 59.

Instrument.—An Arago polariscope used with the naked eye.

Sky about the corona found to be polarized in a horizontal plane.

Mr. Ross* also made an observation with the larger Arago polariscope, holding it so that when looking at a horizontal plate of glass (that is, when the plane of polarization was vertical) the right-hand image was yellow, the left-hand one blue.



On looking at the corona, the appearance represented in the figure was seen, in which horizonal lines represent yellow and vertical blue. He says, "The appearance of the corona was perfectly white, that of the sky around it the opposite of that obtained with a horizontal plate; that is, the blue was on the right." The inference to be drawn from this would be, that the plane of polarization of the sky surrounding the corona was horizontal. "The colours were faint but unmistakable. I did not note the appearance of any colour on the surface of the moon. The colour of the sky in the right-hand image was a dull bluish-purple, the other a dull yellow."

Mr. F. W. Fison. 36° 25′ N. 5° 10′ W. ESTEPONA, SPAIN, 22nd Dec., 1870.

Instrument.—Telescope, with 2-inch object glass, 30 inches focal length, negative eyepiece,† field of view about 1°; alt-azimuth mounting. Polariscope.—Double-image prism, mounted so as just to separate the two images of a slit in the focus of the eye-lens, slit subtending about 1° in length and 15′ in breadth.

* The account here given is by Prof. Pickering.

† The curves of the field lens of Mr. Fison's eyepiece were very deep, and to obviate the slight polarization which would have been caused by the inclination of its surfaces, it was intended that for the purposes of observation the field lens should have been removed, and it was on this supposition that the proportions of the slit were calculated to subtend about 40′ in length and 10′ in breadth. By the introduction of the field lens, and the consequent diminution of the focal image, the breadth of the slit was relatively increased, so that (according

A few seconds after the commencement of totality, the sun emerged from the clouds; it remained visible for a time sufficient to enable me to rotate rapidly the eyepiece with the prism attached, so that the small side of the oblong diaphragm moved tangentially to the whole circumference of the moon. I could not, however, observe with certainty whether there were any differences of tint between the two images, owing to the short time (I should say about 15 seconds) that the total phase was visible, and also to the small amount of light given by the corona, a great portion of which was cut off by the clouds. **Corona visible through cloud. No polarization observed.**

Mr. W. J. Lewis. 36° 25′ N. 5° 10′ W. ESTEPONA, SPAIN, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

Instrument.—Telescope with 4-inch object glass, focal length 63 inches, field of view 5′. Polariscope.—A pair of Babinet's wedges mounted in front of a Nicol.

The telescope used was one of the old collimators of the Greenwich observatory, lent to me for the occasion by the Astronomer Royal. Its focal length is 63 inches, and the aperture 4 inches. At the centre of gravity this was surrounded by a band which was connected by a pivot with an iron bar which served as a cradle. **Description of instrument.** **Strong vertical polarization seen on the corona 30° from the vertex towards the west, 9′ or 10′ from the limb. Observation made through a break of about 15 seconds' duration in cirrus clouds.**

To the eye end of the tube was fixed a bracket having a circular hole in it. In this hole moved a cylinder of brass having an eccentric circular hole in it.

Through this hole passed an iron pin, which was capable of being turned by means of a milled head, within easy reach in two bearings attached to the iron cradle. The portion of the pin passing through the brass cylinder had the same eccentricity as the hole, and could be clamped

to the estimate of Mr. Fison) it subtended two diameters of the sun in length, and must therefore have been at least 15′ broad.

Such a broad slit must have greatly increased the difficulties of detecting radial polarization with a double-image prism, by reason of the great inclination of the planes of polarization a the edges of the slit. Taking this into account, together with the radial depolarization of the field lens, and the amount of cloud (the small particles of which would, as we have before suggested, tend to depolarize by superposing the light from different portions of the corona), it will not be difficult to understand that in 15 seconds Mr. Fison was unable to detect any difference of brightness in the two images.

so that the telescope should either not move on turning the milled head, or describe a cone of any vertical angle less than about 2° at pleasure.

The cradle was mounted equatorially, and moved by clockwork, so as to follow the sun, whilst the telescope could at the same time describe a cone round the sun.

In the common focus of the telescope was placed a Babinet's compensator, consisting of two quartz prisms of the same angle (2°), united by Canada balsam. In both prisms the optic axis is parallel to the external face, but in one it is perpendicular and in the other parallel to the edge.

Just in front of this was placed a sliding diaphragm plate with three holes, giving fields of approximately 3′, 5′, and 8′ diameter.

There was a positive eyepiece with a Nicol's prism packed among its lenses. The direction of the long diagonal of the Nicol's prism, which I shall call the plane of symmetry, could be placed at any angle to the neutral lines of the wedge, and its position was shown by the index. During the fine weather on the 20th and 21st, observations were made to determine whether any traces of polarization due to the telescope could be detected by looking directly at the sun with a coloured wedge interposed in front of the eye, but no bands could be seen. The same result was obtained on describing circles round the sun at distances of about 5′ and 8′ from the sun's limb, and at greater distances. In these observations the two larger diaphragm holes were successively tried.

The morning of the 22nd was cloudy, and at about ten o'clock rain began to fall. The vertical line on my paper circle was determined by holding a plumb-line in front of the circle, when the telescope was placed as nearly as possible in the meridian.

Observations before totality.

About ten minutes before first contact, no bands could be detected in the neighbourhood of the moon, nor could any be detected whilst describing a cone round the sun at a distance of about 8′ from the limb just before first contact. After first contact, the telescope was fixed at several points both on the moon's disc and along the line joining the centres of sun and moon, the whole of the analysing eyepiece being rotated at each point; but not the faintest trace of bands could be seen. The same result was obtained on describing a circle round the sun with the former radius. The diaphragm hole used throughout this day was the one giving a field of about 5′ diameter.

After the last of these observations, about ten minutes before totality, seeing a large rain cloud coming on, I proceeded to adjust my conical motion for the total phase, and in the flurry of making the last adjustment before the sun was obscured, I forgot to clamp my declination axis, and consequently I discovered on looking at my telescope soon afterwards that it did not point towards the sun. The cloud gave us a shower of rain, and seemed so continuous that we gave up all hope of seeing the totality.

The darkness came on whilst the sun was behind the cloud, but about the middle of totality, as it seemed to me, a small break in the clouds showed us the moon and corona. Instantly I altered my declination so as to put me on the corona, and clamped. On looking through my analyser I saw bands which were white-centred, and which became brighter on rotating the analyser from left to right. I turned the analyser until they disappeared, marked the angle on the paper circle, and recorded the observation. Before I could rotate the analyser, so as to obtain the bands of considerable strength, the cloud closed over again, and in about another minute the reappearance of the light showed that the totality was over. Observations during totality.

The sun did not reappear for about half an hour, when I proceeded to determine the point on which my telescope was fixed. As near as I could determine, it was about 30° west of the vertical in the upper quadrant, and about 9′ or 10′ from the sun's limb.

The index was originally placed in the vertical, and the angle at which the bands disappeared was 57°. This makes the angle turned through by the analyser 80° to 82°.

The index was not exactly perpendicular to the bands, but very nearly so; this difference being allowed for, as also taking into consideration the probability of my reading being 2° or 3° too small, owing to my marking off the angle when the bands ceased to be detected, renders it almost certain that one of the neutral lines of the wedge was in the vertical to cause the bands to disappear. This will give for the plane of polarization either the vertical or the horizontal; since, however, the bands were white-centred before disappearing, the plane of polarization must be the vertical, since the bands are white-centred when the plane of polarization and the plane of symmetry of the Nicol are in the same quadrant with respect to the neutral lines of the wedge; and the latter plane was nearly parallel to the index, making an angle of about 80° with the bands.

Although this angle is considerably greater than 45° (the position giving greatest intensity), still very strong bands were seen in previous observations with polarized light, and the fact of the polarization of the corona is thus rendered more decisive, as the bands seen during totality were of considerable intensity. The bands seen were so strong that I feel confident that if the light on the moon's limb or in the neighbourhood of the sun in the preliminary observations were so strongly polarized, I must have discovered bands notwithstanding the quantity of unpolarized light in the field. During the period when the total phase was visible, which I estimate at 10 seconds, light cirrus was passing over the moon and corona.

In the hasty glimpse which I had of the phenomenon I saw some prominences, but did not notice their position. The corona appeared to me to extend at least 16′ from the moon's limb.

Mr. W. H. H. Hudson.

36° 34′ N. } SAN ANTONIO, SPAIN,
4° 16′ W. } 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

Instrument.—Telescope, $3\frac{7}{8}$ inches aperture, focal length 4 feet, negative eyepiece, with a magnifying power of 40. Polariscope.—Double-image prism, with slit subtending in the focus about 50′ by 17′.

Description of instrument.

Polarization detected on moon's surface and also on corona at a part near the vertex. In both instances the slit of the diaphragm was found to be vertical when the two images were of equal intensity.

There was a diaphragm in the eyepiece of the shape of a long parallelogram between the field and the eye-lenses. Outside the eye-lens was a double refracting prism of Iceland spar, which caused such a separation of the images that when it was a maximum the short sides of the parallelogram were in the same straight line, and the adjacent long sides just overlapped. This was the position in which it was used. The cap containing the prism was furnished with a touch-mark consisting of a projecting spoke. When in adjustment, as above described, this mark was parallel to the short side of the parallelogram, and marked the plane of polarization of the image remote from it when the whole apparatus was turned round, so that the difference of intensity was greatest.

A cardboard tube lined with black velvet was fixed at the object end of the telescope, projecting 14 inches from the object-glass, to prevent reflexion from the interior of the tube. On the Friday (the 16th)

preceding the eclipse the instruments were fitted up at San Antonio, three miles or so from Puerto de Santa Maria.

At first the light from almost every object seemed to be polarized. This was accounted for by the want of perfect blackness in the tube of the telescope, and supposed to arise from reflexion in the interior. To correct this a projecting nozzle lined with black paper was first tried, but found insufficient. Black velvet was next had recourse to, and apparently with success.

On the night of the 17th, or rather morning of the 18th, I was observing the moon, and noticed that the light appeared to be polarized, not expecting to have been able to detect the polarization of the light reflected from the moon. I called out to Mr. Moulton, who was observing at the same time, and he had also seen bands across the moon with his instrument.

Polarization observed on the face of the bright moon at night.

On repeating the observation, I detected no polarization, and Mr. Moulton saw no bands.

We were led to account for this by the presence of thin clouds. When the clouds were thick, and when the sky was quite clear, I could detect no difference of intensity on turning the analyser. When there were thin clouds, and even when no clouds were visible to the eye, but when their existence was rendered probable by the neighbourhood of visible clouds, the polarization became manifest.

I subsequently repeated these experiments near the sun at noon, when the sun was so clear that I had to use a dark glass; there were, however, light clouds about. I observed the sky in the immediate neighbourhood of the sun, approximately within a radius of its limb, and at several parts I found the light polarized, the plane of polarization being always radial. Some of these observations Mr. Ladd verified at the time.

Polarization seen within a radius of the limb of the bright sun.

I detected no polarization when thick clouds were on the sun, either on the sun or in its immediate neighbourhood, but at a greater distance—two or three radii from the limb—I found polarization, and again the plane was normal to the limb.

I repeated these observations during the progress of the eclipse after first contact and before totality.

I found polarization on the moon's limb immediately after contact. I found the same again later at 11 h. 32 m. (11 h. 39 m. 20 sec, G. T.); the

Polarization seen on dark moon before totality.

polarization was more decidedly marked, and I determined its plane to be at an angle of 45° to the horizon, and inclined towards the west.

Again, at 3 m. before totality, when thick clouds came on, I found no polarization visible.

I tested the corona for polarization before totality, and found none. This observation was not completed before totality; in the course of it I heard a shout from behind me of "The corona!"

I tested the moon's surface for atmospheric polarization; I found that it was visible, and that its plane was the same as that I had determined before totality as above.

The clouds drifting across the moon were perceptible, and the mountains in the moon were not.

Observation during totality.

I examined the corona for polarization near the apparent upper surface of the moon; I found that it was apparently polarized, and that the diaphragm was vertical when the two images were of equal intensity. I did not determine its plane, but it must have been inclined at 45° to the horizon, and therefore neither radial nor tangential.

I draw the following conclusions from the observations made during the eclipse and during the previous week:—

1. All observations of polarization made with telescopes that have not been previously tested for blackness inside are utterly untrustworthy.

2. That the appearances of polarization are presented when light shines through a thin cloud, whether the said cloud is visible or invisible.

3. That this effect is not produced by clouds above a certain thickness. I estimate the thickness of a cloud by its darkness,—the quantity of light it absorbs.

4. I believe that the polarization of the corona which I detected was simply due to the intervening atmosphere.

I am not perfectly certain of the absolute success of the black velvet arrangement. I think that there may have been some slight reflexion in the tube; had the light been stronger, this might have had a perceptible effect, but as the light was so much cut off by clouds I believe that it was practically successful.

I believe the light was quite sufficient, and the instrument sufficiently sensitive to enable me to speak with great confidence when I determined

that there was polarization, and to prove that when I failed to detect it, it must have been very small. My determination of plane is certainly within 5°, and probably closer.

Mr. Ladd. 36° 34′ N. 4° 16′ W. } SAN ANTONIO VINEYARD, about 3 miles from SANTA MARIA, SPAIN, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

Instrument.—Telescope, 3-inch object glass, power of 40, field of view of about 1°. Polariscope a plate of arragonite, cut perpendicular to one of the optic axes, viewed with a double-image prism.

I looked for polarization on the moon's surface before totality, but failed to detect it until about a minute before the total phase came on; it then increased in amount until the coloured rings were perfectly visible. Strong polarization springing up a minute before totality, stronger on corona than on moon.

On directing the instrument to the corona, I found the rings much brighter and much more distinct than on the disc of the dark moon. The polarization faded off into the clouds.

Professor W. G. Adams. 37° 14′ 0″ N. 15° 13′ E. } AUGUSTA, SICILY, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

Instrument—Telescope with $2\frac{1}{4}$-inch object glass, mounted on an altitude and azimuth stand; focal length 31 inches, diameter of field of view about 50′, magnifying power 25. In the principal focus of the erecting eyepiece was fixed a plate of right and left handed quartz,* with a small Nicol's prism for an analyser.

The rim of sunlight got rapidly thinner and shorter, and was just breaking up into sections of different lengths, when a heavy cumulus cloud came over and obscured the whole. For a full minute after this nothing was seen; but having kept the telescope gradually moving, I then found the moon still in the centre of the field, and saw the dark limb at north and south points well defined, but saw no light of the corona at these points; Corona just visible through cloud. No polarization detected.

* Cut from a natural crystal—with the two fields slightly overlapping at the line of junction.

in the upper left-hand quadrant I saw light of corona and prominences extending over 20° or 30° of the limb, and I also caught traces of light on the west. I could not distinguish any colour or any traces of polarization on these portions of the corona, which were seen through a thinner part of the cloud.

The moon and corona were again obscured, and after a few seconds I again detected light near the point of emergence, and placed it in the centre of the field, with the line of division of my biquartz radial to the moon, but I could detect no trace of colour on the two sides of the crystal.

It was evident that the biquartz was not sufficiently delicate to detect any polarization of corona or cloud under such unfavourable circumstances. The rim of sunlight then became continuous, and totality was over.

Professor Blaserna. 37° 14′ 0″ N, 15° 13′ E } AUGUSTA, 22nd Dec., 1870.

"Rapporti della Commissione Italiana," p. 48.

Instrument.—A small telescope with an erecting eyepiece, giving a power of 30 and a large field capable of containing the whole of the disc of the moon, and a portion of the corona. Between the eyepiece and eye of the observer, was a Savart's polariscope.

Corona seen through opening in clouds during latter part of totality. Polarization at three points on corona near to the sun's limb found to be either radial or tangential. At a distance of 30′ from limb no polarization detected. Clouds before the sun at the beginning of totality—partially clear after.

Il primo momento della totalità non potè esser osservato del posto che occupavo. Un cirro, posto avanti al sole, andava ingrossando più e più, per la successiva condensazione del vapore acqueo, prodotta dal raffreddamento dell' aria nel cono dell' ombra lunare. Nel momento, in cui l'ultimo filetto di sole doveva sparire, una piccola nube opaca si pose avanti al sole, e copri interamente tuto il fenomeno. L' osservazione e con ciò lo scopo, per cui tauta spesa si era fatta di tempo e di danaro, pareva fallita. Ma poco dopo, la nube trasportata dal vento in direzione contraria al movimento apparente del sole, scopri una parte della corona dal lato verso occidente, la quale divenne sempre più e più visibile, e verso la fine della totalità si potè vedere tutta la corona, quantunque velata e frastagliata da sottilissimi cirri.

First observation. Fringes of maximum intensity when tangential at A.

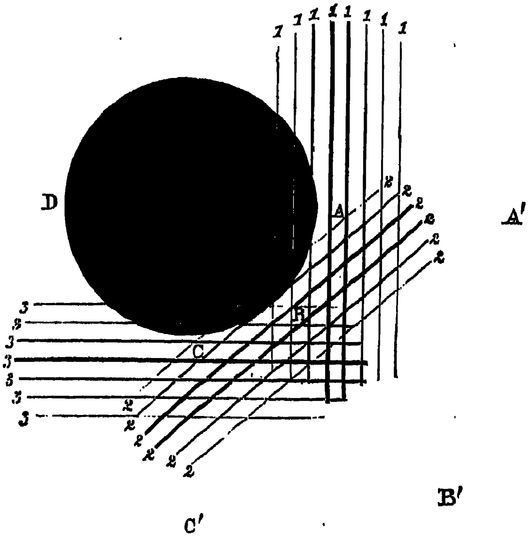
Appena apparve la prima porzione della corona, vi diressi il mio cannocchiale, presso a poco al punto A, e trovai la corona fortemente polarizzata. Ebbi le frange al massimo d' intensità, quando erano parallele

alla tangente al disco solare o lunare, nel modo indicato nella figura colle linee (1, 1).

Girai allora il polariscopio di 90° e le trovai di nuovo al massimo, quando erano nel senso del raggio.

Allora spostai orizzontalmente il cannochiale fino al punto A′ distante da A: di circa un diametro lunare. Il punto A′ era libero di cirri, e non ostante la più grande attenzione e per quanto girassi il polariscopio, non potei scorgere alcuna traccia di polarizzazione. Ritornai col cannocchiale al punto A, e trovai il fenomeno esattamente come prima.

No polarization at A.′



Esaminai quindi il punto B, posto all' incirca 45° più sotto del primo. La polarizzazione era la stessa in quanto a intensità; ma le frange nella loro intensità massima avevano la direzione nel senso della tangente, come è indicato nella figura dalle linee (2, 2).

Fringes tangential at B. None at B′.

Portai il cannocchiale fuori al punto B′ e non vidi nulla.

Allora lo diressi al punto C, situato alla parte più bassa dell'orlo lunare; trovai la stessa forte polarizzazione, e le frange al massimo di nuovo nel senso della tangente (linee 3, 3), mentre il punto C′, ancora immerso nei cirri, non era punto polarizzato.

Fringes tangential at C. None at C.′

Intanto tutta la luna si era fatta libera dalla nube opaca, e tutto il suo orlo appariva circondato dalla corona. Portai allora il cannocchiale al punto D, il quale si mostrò pure fortemente polarizzato, e mentre cercava la direzione delle frange al massimo d' intensità, apparve dal lato opposto il primo raggio di sole, a guisa di luce elettrica, e tutto il fenomeno spari come d' incanto. E per quanto cercassi tutt' intorno, non vidi più traccia di luce polarizzata.

Sun appeared while observing at D

Allora, avendo ancor fresca la memoria del fenomeno osservato, cercai nel cielo sereno un punto, ove l' aria atmosferica mostrasse la polarizzazione d' intensità uguale a quella che avevo visto nella corona. Trovai che se si guarda nel cielo sereno a 50° dal sole, la polarizzazione atmos-

Corona polarization estimated as equal to sky polarization at 50° from the sun shortly after totality.

ferica presenta un fenomeno uguale in forza a quello da me osservato. Nei miei preparativi io mi preoccupava di aver forse da fare con un fenomeno debole: ho trovato invece un fenomeno brillante e cosi facile a verdersi, che in verità non occorre grande abilità per osservarlo.

Faint polarization on moon's disc.

Devo finalmente aggiungere, che le frange erano nettamente visibili, quantunque meno intense anche sull' orlo lunare, come l' ho indicato sulla fig. 1.

Professor W. K. Clifford. 37° 14′ 0″ N. 15° 13′ E. AUGUSTA, SICILY, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

Instrument.—Telescope, 3-inch object glass, diameter of field of view about 35′. Polariscope composed of a pair of Babinet's wedges mounted in front of a Nicol.

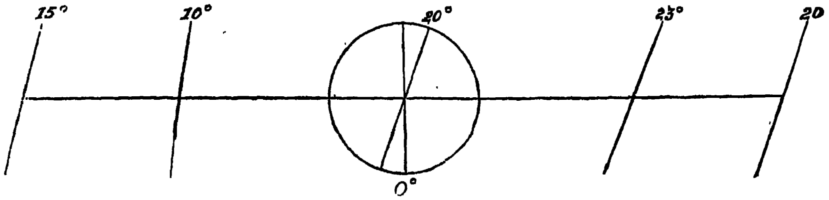
I kept my right eye covered for about an hour before totality. The pointer of the instrument was so arranged as to indicate the plane of polarization for bright centre maximum.

Polarization on moon seen through break in cloud perpendicular to horizon.

Nearly all totality the disc was covered by a cloud, but a break in the cloud passed over it about ten seconds before the eclipse ended, taking four or five seconds in passing. The telescope was then directed to the disc of the moon, and clearly indicated polarization in a plane perpendicular to the horizon.

Polarization on clouds inclined to horizon as indicated in the diagram.

I determined the plane of polarization on the cloud to the right and left of the sun, and on the disc of the moon while it was covered. The results are indicated in the following diagram: in which, however, the positions in regard to the sun must be considered as only approximate. The upper number indicates the reading when the disc of the moon was covered, the lower when uncovered.



A similar diagram was prepared beforehand, with the positions num-

bered in the order in which they were to be observed. After determining the maximum, I called out the number indicated by the pointer, which was written down for me by Sapper Munro, of the Royal Engineers. The lines were distinct all the time, but the position of the maximum was probably subject to an error of about three degrees each way. The observations on the right were made twice over, giving identical results.

At the moment when the cloud was away* I saw the corona; its breadth was about an eighth or tenth part of the moon's diameter, on the side where the sun was about to emerge. I also caught a glimpse of a prominence, but the time was too short to pay any attention to it.

The two positions on either side next the sun were determined by setting the edge of the disc just into the field, the others by guessing the amount of motion of the telescope which was equivalent to the diameter of the sun. This operation had been previously practised The field was a little larger than the sun's diameter.

* From the accounts of other observers stationed at Augusta, it appears that the clouds mentioned by Prof. Clifford were comparatively dense, low-lying cumuli.

It is well known that cumulus clouds are themselves very bad polarizers; any polarization, therefore, which was observed upon their under surfaces must be taken to be the polarization of the intervening column of air, which at Augusta would certainly not have been more than half a mile high; the particles floating in this lower air would be illuminated on their under sides, principally by lateral reflexions from the surface of the sea in the immediate neighbourhood.

This will no doubt explain the great difference between the inclination of the plane of polarization upon the dark moon when uncovered, and when covered by cloud.

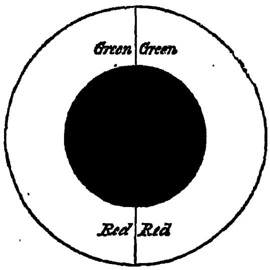
For when uncovered the resultant plane of polarization is determined by the illumination derived in all directions as far as the limit of the atmosphere; while when covered it is more dependent upon the local causes near to the observer. At Augusta the observers were situated on a narrow neck of land, and a line drawn through their station perpendicular to the azimuth in which they were observing would have passed in the one direction out to sea over a good reflecting surface, while in the other direction it would have passed over a little bay of not more than a mile in diameter and then over the land.

This would cause the lateral illumination of the lower air to be greater from the S.E. than from the N.W., and may account for the inclination to the horizon of the lower-air polarization.

While the higher-air illumination would in a great part be derived from light which had been reflected from the upper surfaces of clouds and from a much larger extent of country, we might therefore expect to find the resultant plane of polarization more nearly perpendicular to the horizon.

green;* below the moon they also matched, and I noted them as red and red.

The accompanying figure represents my field of view. I did not pay attention to the series of colours intervening on either side, and can only speak positively as to the following facts.



1st. That the vivid colours extended as far as the edge of the field of view.

2nd. That the colours on either side of the line of junction, both above and below, matched.

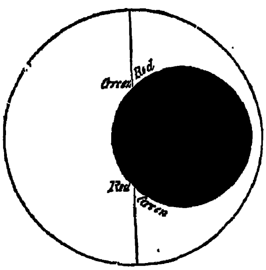
3rd. That green was the prevailing colour of the area above the moon, and red the prevailing colour below.

4th. That the moon was comparatively colourless.

Having made a note of the position of the colours—with regard to the line of junction—I passed on to my second observation.

Second observation.

The line of junction was shifted parallel to itself, till it cut off an arc of some 90° from the moon's eastern limb.



The colours on the corona contiguous to the line of junction were now widely different. At the upper limb the field was green upon the left hand and red upon the right, while at the lower limb the colours were reversed, and the red field was upon the right hand while the green was upon the left.

My attention was so entirely devoted to noting the colours near to the line of junction, that I did not even remark whether they extended as far as the eastern edge of the field, or what were the colours on the other parts of the corona.

First observation repeated.

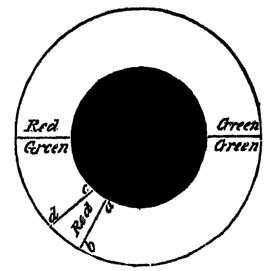
After making a note of the position of the colours, I moved the line of junction back till it bisected the moon, and repeated the first observation. I noted again, as before, that the colours at the line of junction matched, and were green above the moon and red below. By *at the line of junction*, I mean that my attention was directed to an area of say, 8′ or 10′ in diameter, abutting on either side of the line of junction,

* See the second note on p. 267. See also Professor Pickering's observation with a biquartz, giving the sensitive tint, on p. 299.

and that the general effect of colour from such area was green above and red below.

I then moved the line of junction into its old position in observation No. 2, and noted that the colours wereas before strikingly different on either side of the line of junction; green and red above and red and green below. Second observation repeated.

I then turned the eyepiece and quartz plates through a right-angle, so that the line of junction was now horizontal, and the moon was brought to the centre of the field. The colours were as in the fig. On the right hand—that is, on the moon's western limb—they matched on the two fields, and I noted them as green and green; but on the left-hand side they did not match, and I placed upon my notes, 'red* above and green below;' but what tints of red or green these words refer to, I am not now able to recall. Third observation.



My attention was taken by a red ray, with sharply defined edges, in the lower left-hand quadrant. At first the idea passed through my mind that it must be caused by a flaw or small cross crystal in the biquartz; but I had observed none before, and it shifted with the corona as I moved the telescope. I felt very uneasy, as if I were observing something which ought not to be there; but, nevertheless, made a note of the ray, drawing at the time two lines in my note-book, to represent its edges, and writing the letter R upon it, to signify Red. The two lines were very hurriedly drawn, and I am not sure that their inclination and position even approximately represent the inclination and position of the edges of the ray. The two lines *a b* and *c d* in the last fig. are in the position of the marks made on the note-book at the time.

Totality was passing very quickly, and the sapper, who was counting the seconds, now gave the time as ten seconds more. I therefore left the large telescope, and before applying my eye to the finder, gave a passing look at the corona with my undefended eye, but was completely dazzled by its light, and the only impression which I derived was of brilliant, spurious rays, springing from all sides of the moon.

I then went to the finder, just in time to see that there were bright colours upon the corona, but I had not noted the position of any of the colours when the sun began to reappear. With second instrument bright colours seen on corona.

* See the note on p. 271.

Mr. H. Samuelson, M.P. Near VILLASMUNDA, SICILY, 22nd Dec., 1870.

"Nature," Feb. 16th, 1871, Vol. iii., page 311.

Instrument.—Savart with naked eye.

Air polarization in neighbourhood of eclipsed sun observed to be vertical during totality.

During the time occupied in perfecting the necessary preliminaries I noticed the position and the structure of the cloud-banks, which were instilling into our minds feelings of the keenest anxiety. We were standing in the centre of what I may describe as a comparatively cloudless longitudinal "slit" in the sky, which was otherwise completely covered; so that while over our heads the sun was shining brightly, its refulgence obscured only occasionally by light fleecy flying clouds, to our front and rear were lying parallel lines of heavily-banked "cumuli-strata," running from north-west to south-east.* During totality I made the following observations with a Nicol's prism and Savart's plates, in the use of which instrument Mr. Ranyard had instructed me, and with which I had constantly practised during our week's preliminary residence in camp at Augusta: viz., I determined the polarization of the sky at two points,† (1) high up on the sky to the S.E. of the sun, (2) under the sun; and at both these points I found the plane of polarization to be vertical. Totality ceased while I was making a third observation.

Prof. C. S. Peirce. VILLA SAN GIULIANO, NEAR VILLASMUNDA, 22nd Dec., 1870.

"United States Coast Survey Reports," 1870, Appendix 16.

Instrument.—A telescope and Savart's polariscope.

Seen through opening in clouds. Polarization at two points upon the corona, each about 6′ or 7′ from the moon's limb, and differing in position angle by about 90°, found to be nearly radial, being inclined about 6° more towards the vertical.

(p. 11.) Fortunately, a very small opening occurred in the clouds, so that the observations could be made, although under disadvantageous circumstances. I had previously tested the telescope for polarization, and found none perceptible. The plan was to set first upon the dark face of the moon and turn the polariscope so that the bands disappear, and then

* The two cloud-banks were approximately at right-angles to the azimuth in which we were viewing the sun. See a small sketch map given in "Nature," Vol. iii., p. 310.

† According to Mr. Samuelson's verbal description, given a few minutes after the end of totality, point (1) was situated about 15° from the sun, at about the same altitude as the sun; point (2) was 8° or 10° below the sun.

observe the position angle (from the centre of the moon) of that part of the corona on which the bands attained their maximum. I observed two parts of the corona, differing 180°* in position angle, and found the plane of polarization to be about 6° from the radial position, being more nearly vertical. The parts observed upon were 65° and 145° from the vertex towards the east in position angle. The measures were made upon a part about 6′ or 7′ from the limb. The measures both of the position of the plane of polarization and of position angle were recorded by scratches upon the lacquer of the eyepiece, the edge of the polariscope affording the means of measuring the latter.

Prof. Eastman. 37° 3′ 53″ N. 15° 16′ W. } SYRACUSE, 22nd Dec., 1870.

"Washington Observations," 1870. Appendix I., p. 126.

Instrument.—Equatorial telescope 3·25 inches in diameter, and a Savart's polariscope.

[At the commencement of totality] I turned the telescope upon the dark face of the moon, and saw alternate dark and light bands of nearly equal intensity over the whole surface; but the distinction was a little less marked at the centre of the moon. These bands were not changed in distinctness or tint during a complete revolution of the polariscope. I then moved the telescope so as to take successively into the field portions of a belt of the sky outside the visible limits of the corona, extending completely around the moon; but the alternate dark and light bands remained the same in tint, though they varied in intensity or distinctness, according to the position of the clouds. Where the sky was nearly clear of clouds the definition of the bands was about the same as on the dark surface of the moon, but the definition was very much improved whenever a denser portion of the cloud was in the field.

Observation made through clouds. Traces of polarization found upon the moon and upon the clouds outside the corona. The telescope was then moved so as to keep the lower and denser portions of the corona near the middle of the field, and the bands were found to be at their maximum when tangential and normal to the moon's limb.

I then moved the telescope around the moon in such a way as to keep the lower and denser portion of the corona near the middle of the field, with results similar to those derived from the examination of the sky beyond the corona, except that the intensity of the tint of the bands was at its

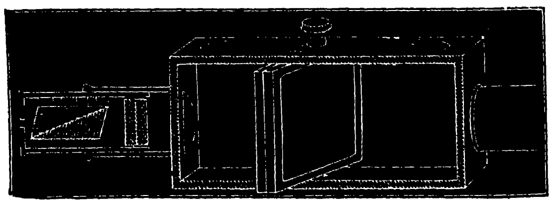
* Query 90°.

maximum when they were parallel or perpendicular to a tangent to the moon's limb. Once I thought I detected a faint tinge of green in the bands, but I was not able to see it again. I also saw a faint but decided red tinge in the bands over what I at first took to be a very dense portion of the corona on the south-west limb of the sun, but on more careful scrutiny it proved to be a cloud moving easterly.

Mr. G. Griffith. 37° 3′ N. } 15° 16′ W. } SYRACUSE, SICILY, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

Instrument.—Telescope, 3¼ inches aperture, focal length 50 inches. The polarimeter consisted of a Savart's polariscope, with four plates of glass placed in front of the eyepiece to be used as depolarisers. A small index moving over a graduated card disc* indicated the angle which the plane of polarization made with any fixed line. A similar index was attached to the glass plates, to indicate the angle through which they had been turned when the fringes disappeared.



Seen through break in clouds, plane of polarization on moon 10° from vertical towards the west; polarimeter plates turned through 32.° On corona, near lowest point of moon's limb, plane of polarization parallel to the former plane, but polarimeter plates turned through 37°. 135° from vertex towards the west, plane of polarization 3° from the vertical, plates turned through 39°.]

The principal section of the Nicol's prism was placed at right-angles to the plane of reflexion of the glass plates, and when the latter plane coincided with the plane of polarization of the light examined, the white-centred fringes were of maximum brightness, and at right-angles to the plane to be determined.

In some preliminary experiments we had ascertained that when the quantity of polarized light under examination was small, or when it was accompanied by much unpolarized light, it was difficult to determine with certainty and rapidity whether the fringes were dark-centred or white-

* This graduated card disc is not shown in the figure; it was attached to the body of the telescope so that the tube on the right hand could be passed through its centre and fit into the adapter of the telescope. The index showing the position of the plane of polarization was fixed at right-angles to the tube, so as to revolve with the box of the polarimeter.

centred, until the plates were moved from their zero position; when this was done the intensity of the fringes increased if they were dark-centred.

On the morning of December 22nd, soon after ten o'clock, a cold wind began to blow with an intensity which went on increasing until the time of totality was over. About twenty-five minutes before the commencement of totality a dense cloud passing up from the S.W. came over the sun, and our prospects of witnessing the phenomena of totality became very gloomy. A few minutes, however, before 2 p.m., the small crescent of the sun was to be seen not far from the edge of the cloud, which was moving away with great rapidity. This fact, coupled with the general impression left on my mind, leads me to think that the cloud must have had well defined limits, and that at the commencement of totality nearly all traces of it had passed away from the region of the sky which was between us and the moon. It was also noticed, that the spaces between the clouds were of a clear blue colour.

Polarization at centre of dark moon.

As soon as the last trace of the sun's disc had disappeared, the central part of the moon was brought into the middle of the field of view. The Savart's bands were at once seen with great distinctness, and the polarimeter was rotated so as to produce the maximum of brightness in the bands. As had been anticipated, I was unable to determine with certainty whether they were dark or white centred, and on turning the plates, it was immediately seen that they were dark-centred; to make the observations as good as possible, the plates were brought back to zero, and again turned with a similar result.

The polarimeter was then turned through an angle of 90°, and the bands became white-centred and of maximum intensity. The plates were then turned until the bands disappeared.

The plane of polarization of the light under examination made an angle of 10°, with the vertical inclining towards the west. The angle through which the plates had been rotated was 32°. This completed the first observation.

Polarization on corona near to lowest part of limb

It was intended that my next observation should be of the light of the corona at a distance of about 4′ or 5′ from the vertex of the sun. My telescope, however, which had to be clamped during any observation, was accidentally moved by the assistant, who turned the clamping screw towards the opposite limb; and to avoid any loss of time, however small,

I had the telescope fixed for observing the extreme south portion of the corona.

The quantity of unpolarized light radiated from the spot observed was considerable, the Savart's bands being seen on a bright background.

The intensity also of the polarized light *seemed* to be much higher than that on the moon's surface, where I had experienced more than usual difficulty in determining the plane; but in the present observation the difficulty was still greater. After turning the polariscope about, the plane was at length determined, and the plates of the polarimeter were turned as before.

On examination afterwards, this plane was found to coincide exactly with the previously determined plane, but the angle of rotation of the plates was greater—viz., 37°.

Polarization on corona 135° W. of vertex.

So much time had been spent on these observations, that it now seemed possible to make only one more pair. The telescope was accordingly directed to what appeared to be the brightest part of the corona, adjacent to the spot last observed; this was not far off from the point where the sun's light would first reappear, about 135° from the vertex towards the west. Here I noticed that the bands were not equally bright all over the field of view. Both here and in the observations already described, but especially in the first, the bands seemed to consist of only a few colours. They were still to be seen on the moon's disc, a portion of which formed the lower part of the field.

The plane of polarization of the light examined in this observation was less than 3° from the vertical, and the angle through which the plates were turned was 39°. When this observation was completed totality was ended.

Conclusions.

These observations seem to show, therefore, that nearly five-sixths of the polarized light coming from the corona near the sun's southernmost point was due to the same cause as that which seemed to come from the moon's disc. At a spot some 45° from this, a somewhat larger amount of polarized light was measured, and the plane made only an angle of 7° with the former plane. This angle exceeds the limits of error in any of the preliminary experiments, even when much smaller quantities of light were examined; that is, in rapid successive observations of the same spot of the sky or a cloud the discrepancies were less.

I am inclined, therefore, to believe that the two planes were not identical. The increased quantity may possibly be explained by the increased brightness during the latter part of the totality of that part of the corona.

How far these observations were affected by the presence of cloud is as important as it is difficult to determine. No cloud was *observed* passing between the eye and the moon during the first set of observations. I believe, however, that some of the photographs taken by Mr. Brothers during the early part of totality show traces of the presence of clouds.

That there was little or no cloud during the latter part is fairly proved by the excellence of the photographs taken during that period.

Any further discussion of the nature of the corona, so far as it can be determined by a knowledge of the state of its light as regards polarization, based upon my observations alone, would evidently lead to no useful result; I trust, however, that, compared with the observations made at other places and by other observers, they may be of some service in determining its complex character.

Prof. Harkness. 37° 3′ 53″ N. } SYRACUSE, 15° 16′ W. } 22nd Dec., 1870.

"Washington Observations, 1869," Appendix I., p. 80.

Instrument.—Arago polariscope employed with diaphragm and without diaphragm.

During a rapid observation atmospheric polarization detected. When two fields of sky polarized in contrary planes were superposed by means of an Arago used without a diaphragm, the sky and corona appeared of their natural colour.

I spent the first ten or fifteen seconds of the totality in examining the corona with an Arago polariscope. The instrument consists of a plate of selenite and a double-image prism, placed almost in contact with each other, and mounted in a brass cell 0·43 of an inch thick, for the purpose of slipping on to an eyepiece, so that it may be used for telescopic observation. The eyepiece contains a diaphragm of such diameter that when it is seen through the polariscope two circular fields of view appear, tangential to each other; and if polarized light is present these fields of view are of complementary colours. When the cell is removed from the eyepiece its field of view has no longer any well-defined boundary, and if a beam of polarized light is then examined with it the effect of the prism will be to displace one portion of the beam upon another, and no complementary colours can appear except at the very edge of the field. Now, bearing in

mind that the separating angle of the prism is 2° 31′, let us apply this to the case of the eclipse. Looking at the corona through the polariscope, two images of it will be seen well separated from each other, and everywhere else one portion of the sky will be displaced upon another portion 2° 31′ distant. Under these circumstances, no matter whether the sky is polarized or not, it can exhibit only its natural colour, unless, indeed, the polarization varies so rapidly that its difference at points 2° 31′ apart is sensible in the instrument. If the corona is polarized in the same plane, and to precisely the same extent, as the surrounding sky, the two images of it will also appear of their natural colour; but if it is either more or less polarized than the surrounding sky these images will be of complementary tints, and the arrangement of the tints will show whether the polarization is radial or confined to a single plane. In order to discriminate between the cases where the corona is polarized to an extent different from the surrounding sky, or not polarized at all, it will be necessary to examine it with the same polariscope, provided with a diaphragm so arranged as to exhibit two fields of view tangent to each other. Then, if the corona is polarized, the two images will be of complementary tints, while if it is not polarized they will be of their natural colour. The experiments I tried were therefore as follows:—

Observation. First I employed the polariscope provided with a diaphragm, and I saw that in each field the sky and the corona were of the same tint, but in the two fields these tints were complementary to each other.

Next I employed the polariscope without the diaphragm, and I then saw the sky of its natural colour, and the two images of the corona also of their natural colour. Clearly, the inference to be drawn from these observations is that, so far as the instrument was capable of determining, the light from the sky and that from the corona were polarized to the same extent; and knowing that the polarization of the sky is produced in our own atmosphere, I infer that that of the corona had the same origin, and therefore that when the light was emitted from the corona it was not polarized at all. As the tints were faint it was difficult to determine the plane or planes of polarization, and I could not spare the time * for the attempt.

* In Captain Tupman's report, at p. 117, he estimates that Prof. Harkness could hardly have been occupied with the polariscope for ten seconds.

Mr. J. Norman Lockyer.

12° 25′ N.} BEKUL,
75° 0′ 6″ E.} 12th Dec., 1871.

"Nature," Vol. v., p. 218.

Instrument.—A small telescope with a low-power eyepiece and a field of 3° or 4° in diameter, used first with a Savart's polariscope and secondly with a biquartz.

I next went to the polariscope, for which instrument I had got Mr. Becker to make me a very time-saving contrivance—a double eyepiece to a small telescope, one containing a Savart and the other a biquartz. In the Savart I saw lines vertical over everything—corona prominences, dark moon, and unoccupied sky. There was no mistake whatever about this observation, for I swept three times across, and was astonished at their unbrokenness.

1. With Savart, lines vertical over everything. 2. With biquartz, wedges faintly coloured yellowish, brownish, and green on each side of the line of junction 3. Vertical air polarization, visible for 3 m. after totality.

I next tried the biquartz. In this I saw wedges faintly coloured here and there; a yellowish one here and a brownish* one there, with one of green on each side of the junction, are all the colours I recollect. . . .

Three minutes after the eclipse was over I returned to the Savart, and saw exactly what I had seen during the eclipse: the vertical lines were still visible!

Mr. J. Broughton.

11° 24′ N.} DODABETTA, NEAR OOTACAMUND,
76° 43″ E.} 12th Dec., 1871.

Report of Colonel Tennant, Calcutta, 1872, p. 13.

Instrument.—Savart's polariscope,† and naked eye.

No polarization was observed near the sun until the instant of totality, when the bands instantly and strongly appeared with the light of the corona, etc. I could see no change in the polarization in about half a degree from the sun, though of course the light was fainter. The plane of polarization was that of the vertical, through the sun's centre (*i.e.*, the bands were quite perpendicular to the eye), when strongest.

Polarization sprang up at totality. Bands a maximum when vertical. No bands seen on moon's disc.

I had previously set the polariscope by the sunlight reflected from the surface of water. I could see no faint bands by looking at the moon's disc.

* See remarks on p. 267.

† Mr. Ladd informs us that the field of the Savart made use of was certainly more than 10° in diameter, and that the thickness of the quartz plates was such that as used with the naked eye the bands would each subtend about one-third of a degree in breadth.

Mr. G. K. Winter. INDIA, 12th Dec., 1871.

The "Philosophical Magazine" for March, 1872, pp. 191-3.

Instrument.—Telescope, 2·75 inches aperture, and 30 inches focal length, mounted equatorially. Polariscope.—Savart, with polarimeter of four plates.

The corona close to the moon's southern limb was found to be radially polarized. At a distance of 10′ from the limb the amount of polarization was found to be considerably greater.

Although quite convinced myself of the fact of the radial polarization of the corona, I was anxious this time to place it beyond doubt by taking actual measurements of it in such a position that if the polarized light proceeded from the unobscured portion of the earth reflected into the atmosphere, and again back to the eye, it could not be measured. I therefore chose the southern limb for my observations, and carefully got my bands radial to the sun, and consequently making but a small angle with the horizon before totality, keeping the field as nearly as I could in the same position-angle with respect to the sun by means of the right-ascension tangent-rod during totality.

Immediately totality commenced the white-centred bands appeared. I turned the axis of the frame with the glass plates until the bands disappeared. The angle the plates had to be turned through was 35°.

I then turned the declination tangent-screw slightly, so as to get a portion of the corona a small distance from the limb (I think about 10′) into the field. The plates had then to be turned through an angle of 45° before the bands disappeared. Three other measurements were taken in about the same position, the result showing that the polarization increased considerably with distance from the limb.

No polarization observed on the moon's disc.

It is evident that if the polarized light were really due to the reflexion from the unobscured portion of the earth, it would be polarized in a plane nearly at right-angles to the plane of my bands, and consequently its polarization could not be neutralized by the plates of glass in the position in which they were used. When the plates were inclined so as to neutralize the corona polarization, I saw faint black-centred bands on the portion of the moon's disc in the field. I did not observe any when the plates were at right-angles to the axis of the telescope, but I think I should have noticed them if they had existed; so that although there was a sensible amount of light on the moon's disc, sufficient to show bands when polarized by the glass plates, I do not think it was perceptibly polarized itself.

The glass plates used in the polarimeter were the thin plates used for mounting microscopic objects. I have not yet determined their refractive index; but, supposing them to be of crown glass, and that $\mu = 1{\cdot}54$, then from the table given in Professor W. G. Adams' paper in the March number of the *Phil. Mag.* for 1871, we get the following figures for the proportion of polarized light as shown by my measurements:—

		Angle of Plates.	Proportion of Polarized Light. Whole Light = 1.
1st	Close to the limb - - -	35°	·158
2nd	At about 10′ distance from the limb - -	45°	·257
	" " - -	40°	·212
	" " - -	45°	·257
	" " - -	45°	·257
		Mean of 2nd series	·24575

Mr. W. J. Lewis. 9° 40′ N. 79° 59′ E. JAFFNA, CEYLON, 12th Dec., 1871.

MS. Reports of the 1871 Eclipse Expedition.

Instrument.—A refracting telescope of 3·75 inches aperture and 63 inches focal length, mounted so that the telescope could be readily carried round the corona at a small height above the moon's limb. Polariscope.—A pair of compensating quartz wedges, with angles of 2°, placed in the focus of a positive eyepiece, and a Nicol's prism between the eyepiece and eye.

The instrument employed for investigating the polarization of the corona was, with the exception of the stand, the one that I used for similar observations in Spain on the occasion of the total eclipse of the sun on the 22nd of December, 1870. The equatorial stand, which was kindly lent by Lord Lindsay, was so constructed that the polar axis could be adjusted for any latitude exceeding 38°; and to render it available for observations at a station near the equator, a brass piece, equivalent to a wedge having an angle of 33°, was introduced between the part immediately supporting the polar axis and the horizontal base of the stand, on which the clockwork was placed.

No traces of polarization could be detected in the neighbourhood of the sun before totality. 1. At the beginning of totality strong black-centred bands indicating radially polarized light were observed on a part of the corona 6′ or 7′ from the limb. 2. The telescope was then moved round the corona, and the bands were observed to fade and then reappear as white-centred, and then again to fade and reappear as black-centred. The interval

The telescope, for which I am indebted to the kindness of the Astronomer Royal, was one of the old collimators belonging to the Greenwich Observa-

between two successive disappearances seemed about 90°. 3. The bands were observed to disappear when the telescope was directed to a point on the horizontal diameter through the sun's centre.

tory, the object glass having a focal length of 63 inches and an aperture of 3·75 inches. The telescope was connected with the declination axis by means of an intermediate piece of apparatus, which enabled the observer to make the axis of the telescope describe a conical surface, the angle of the cone being capable of adjustment to any angle not exceeding 2° 15′.

The vertical angle of the cone employed in observing the corona was about 45′, and the telescope was so arranged that the centre of the field was in every position between 6′ and 7′ from the sun's limb. In different positions of the axis of the telescope, whilst describing this conical surface, the principal plane of the Nicol's prism, and the analysing eyepiece retains the same position in the telescope, and makes a small angle less than 45′ with its original position; it may therefore be considered to retain a constant direction.

The analyser consisted of a pair of compensating quartz wedges, having angles of 2°, as suggested by Prof. Stokes. These were placed at the focus of the positive eyepiece of the telescope. The Nicol's prism was placed between the eyepiece and the eye, and so arranged that the principal plane of the Nicol's prism was, as nearly as possible, inclined at 45° to the line of bands, seen when the instrument is directed to objects whose light is plane-polarized, and for which direction the term "neutral line of the wedges" is convenient. By this arrangement the bands were black-centred and strongest when the principal plane of the Nicol's prism was in the plane of polarization. By "principal plane of the Nicol's prism" is meant that plane which is parallel to the principal plane in the crystal from which the prism has been made, and is perpendicular to the plane of analysation of the light passing through the Nicol's prism.

Observations.—Some days before the eclipse the telescope was directed to white clouds in different portions of the sky, but the maximum amount of polarization observed was so small as to justify me in considering the telescope free from any polarizing influence.

During the partial phases observations were made to determine whether polarization could be observed, especially in the neighbourhood of the moon; but no trace of bands was seen.

First observation

The telescope was initially directed to a point in a plane parallel to the earth's equator, passing through the sun's centre at a distance of about 6′ or 7′ from the limb. The eyepiece had been placed with the neutral line

of the wedges approximately in the vertical plane, passing through the sun's centre, and a diaphragm-plate having a circular hole such that the field of view was about 5′ was used. On observing the corona after the commencement of totality, strong black-centred bands were seen. The vertical plane passing through the sun's centre and the equator includes an angle of about 29°, and therefore the angle included between the principal plane of the Nicol's prism, which was about 45° to the right of the neutral line of the wedges, and the radial plane, was nearly 74°. Under these circumstances light polarized in the radial plane would give black-centred bands.

The telescope was then slowly moved by means of the conical motion, so that the centre of the field was always about 6′ or 7′ from the sun's limb, and that, as before shown, the principal plane of the Nicol's prism and the neutral line of the wedges remained practically parallel to their initial positions. During this revolution the lines were observed to change in intensity, gradually and without discontinuity, until finally they disappeared. On continuing to revolve the telescope, bands of a complementary character (that is, white-centred) appeared, gradually increased, and then diminished in intensity until they again disappeared, and afterwards reappeared, with a central dark band, and so on. The interval through which the telescope was moved between two successive disappearances of the bands seemed to be about a quarter of a complete revolution, though no accurate measurement of this was made. A second hole in the diaphragm-plate, giving a field whose diameter was about 9′, was then used, and the same series of observations repeated with similar results. Second observation.

At one point during the latter revolution a prominence was noticed on one side of the field of view, and the bands were observed to be very faint, and to make but a small angle with the radial plane.

One of the positions of the axis of the telescope, at which the bands disappeared, was determined as nearly as possible. The bands were found to vanish when the telescope was directed to a point on the horizontal diameter of the sun. As the neutral line of the wedges was vertical, this observation proves that the plane of polarization at this point was either vertical or horizontal. Third observation.

From these observations it is seen that the plane of polarization is not fixed, but that it changes as the direction of the radius changes; that at four different points the plane coincided with either the radial or tangen-

tial plane; and lastly, from Observation 1, that it cannot be tangential, but must coincide with the radial plane. Moreover, since the maximum intensity of the bands was very considerable, the light is in all probability polarized by reflection from some substance in the immediate neighbourhood of the sun.

The greatest angular distance from the sun's limb included in the field of view, during any of the observations, was about 11′ or 12′.

Capt. Tupman. 9° 40′ N. } JAFFNA,
79° 59′ E. } 12th Dec., 1871.

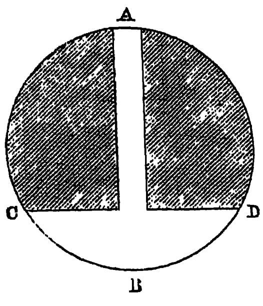
MS. Reports of the 1871 Eclipse Expedition.

Instrument.—A three-inch achromatic telescope of fifty inches focal length, with a negative eyepiece of power 45 or 50 and a field of 41′ in diameter. Outside the eyepiece was fitted a Savart's analysing apparatus, with very thick quartz plates, giving six bands in something less than 5′ of arc as seen in the telescope.

Ten seconds after totality, at 45° from the sun's vertex, the bands were visible to a distance of nearly 40′ from the limb. They were of maximum intensity when radial. Near the vertex, at 30 s. after totality, they were also of maximum intensity when radial. 10 m. before the total phase no bands could be detected in the sun's neighbourhood.

The Nicol's prism of my Savart was cut as short as possible, so that the entire field of view of the eyepiece could be taken in at once; and the plates were set so as to give bands coincident with the principal plane of the Nicol black-centred when in the plane of polarization.

In the focus of the eye-lens I introduced a diaphragm, which is represented in the annexed figure. The parts shaded were stopped out. The object of this arrangement was to enable a radial portion of the corona to be isolated—the edge C D being convenient for setting a tangent to the limb. The length from A to B was 41′. The line C D was 10′ from the limit B of the field, and the width of the slit A B was 4·7′. The principal plane of the Nicol and the Savart bands coincided longitudinally with the slit, there being just six bands in that width.



Observation.

During totality I made no polariscopic observations; but some ten seconds after the reappearance of the limb of the sun (the corona being still very bright and extensive above the sun and on either side) I quickly set the finder, and applied my eye to the polariscopic telescope, which had been carefully set during the partial phase, so that the slit A B was inclined

45°, by estimation, to the horizon. The limb of the moon was just within the field at B, and the Savart bands, exceedingly distinct and slightly coloured, extended from close down on the prominences at B to the other extremity without appreciable change in intensity. I did not notice whether they were black or white centred, but rotated the eyepiece both ways, and found the bands of maximum intensity when the slit and bands were radial to the moon's limb.

I then moved the polariscope bodily upwards some 30° or 35° along the limb of the moon. As I did so the bands became fainter; but on rotating the eyepiece as before, they again attained their maximum intensity when radial. The point A was never less than 35′, and at times was 38′ or 39′, from the limb of the moon (the distance from A to B, as I have said before, was 41′), and still the bands were quite strong there at both observations.

Imagining that there was yet time for another observation, I went to the finder to adjust on the other side of the sun, when I was dazzled by the light, and did no more. Had I not left the polariscope, I am certain I could have made one, if not two more observations, before the increasing sunlight overwhelmed the polarization of the corona.

My last observation was made possibly 30 seconds after totality—an interesting fact that future observers will take advantage of.

A quarter of an hour or ten minutes before the total phase, when setting the polariscope, I could detect no traces of polarization. It follows therefore that the light of the corona is strongly polarized at a distance of 38′ above the photosphere, and in all probability very much higher. I should mention that during the observations I was not in the least nervous or excited.

SUGGESTIONS FOR POLARISCOPIC OBSERVATIONS OF FUTURE ECLIPSES.

1. No observations have, as far as we are aware, been made to determine the distance from the sun's limb at which traces of polarization due to the corona can be detected.*

* See the method suggested in the note on pp. 256-7. The polarimeter should also be made use of to determine the extension of the coronal polarization above and below the sun, and in other directions, especially in the neighbourhood of the sun's polar and equatorial regions.

2. It would also be desirable to measure as accurately as possible the height above the sun's limb at which the polarization of the corona is strongest. This height should be determined at several parts of the corona—*e.g.*, in the neighbourhood of the sun's poles, and near to the sun's equator. A measurement should, if possible, be made within the area of a rift, and it should be especially noticed whether the height of the area of maximum polarization * is the same within the rift as upon the coronal matter in the neighbourhood.

3. The light from the lower parts of the corona adjacent to the moon's limb should be examined with a biquartz, in the manner recommended by Professor STOKES. For this purpose a moderately high power should be used, and the observer should note whether the tree-like forms, bright rays, or other structures that may be visible in the corona, are uniformly polarized with the background of coronal matter upon which they are seen. If the brighter details are found to be less strongly coloured, the observer should note the parts of the structures where the difference of tint between the structure and its background is greatest.

4. With regard to the polarization of the atmosphere during totality, observers should endeavour to determine with certainty whether the light derived from the atmosphere about the sun's place is polarized in a horizontal or vertical plane. † It would be well if several observers would each undertake to give their attention to the polarization of one particular part of the heavens. Their observations should be made with polarimeters, so that changes in the intensity of the polarization may be noted, as well as changes in the position of the plane, as the area of darkness passes over the observer's station. Observations of the polarization of the heavens near to the zenith, and of various parts of the heavens near to the horizon, should, if possible, be made, as well as careful observations of the polarization about the sun's place. If the sun is obscured

* The height of the area of maximum polarization may be determined with a Savart polarimeter by turning the plates till the bands are reversed; the area of the field where the bands are last reversed or last extinguished will be the area of maximum polarization; the centre of the field should be marked as recommended in the note on p. 257, and a scale of minutes should also be etched on the glass plate. For diagrams of a convenient form of polarimeter, see pp. 294, 318.

† The observations of MAUVAIS, 1842, PICKERING, 1869, CLIFFORD, SAMUELSON, and PIERCE, 1870, LOCKYER and BROUGHTON, 1871, only go to prove that the polarization of the atmosphere is either horizontal or vertical. ROSS'S observation, 1870, would give the polarization as horizontal instead of vertical, as is usually assumed. GRIFFITH'S observation, 1870, is the only one which tends to show that the atmospheric polarization was nearly vertical; but it will be noticed that he does not mention the position of his polarimeter box. During his first observation at the moon's centre, the polarimeter box was evidently at right angles to the plane of polarization, and it seems, perhaps, more natural to assume that he commenced his observations with the polarimeter box in a vertical rather than in a horizontal position.

A particle floating in the atmosphere within the area of totality, illuminated by light derived from the clouds upon the horizon, would be exposed to ethereal agitations parallel and perpendicular to the plane of the horizon. The particle would become the centre of secondary waves, of which the amplitude perpendicular to the horizon would evidently be greater than the amplitude parallel to any particular azimuth. We should, therefore, from theoretical considerations, expect the light dispersed by such a particle in any direction other than vertically upwards and downwards to be polarized in a horizontal plane. If the illumination were uniform on all sides, particles floating in the air directly above the observer should give unpolarized light; in all other parts of the heavens the plane of polarization would be horizontal. (This note must be taken as overriding the opinion expressed upon p. 255 with regard to the vertical nature of the atmospheric polarization.)

by clouds during totality, observations of the polarization of the atmosphere near to the horizon and upon the under surfaces of clouds will still be of interest. Observers who give their attention to the polarization of the atmosphere should note the time and the part of the heavens in which the ordinary radial polarization of the atmosphere is first seen to be disturbed before totality, and they should watch the manner in which the ordinary radial polarization of the heavens changes into the polarization observed during totality.—A. C. RANYARD, 1876.

The following suggestions for polariscopic observers were printed in a pamphlet circulated by the committee of the British Association which was appointed to organize the expedition to observe the eclipse of 12th Dec., 1871 :—

SUGGESTIONS BY MR. RANYARD. (*August*, 1871.)

1. To determine the plane and measure the amount of atmospheric polarization in at least three points, about 8° or 10° away from the sun's place. The points to be chosen round the sun, say N., N.E., and E., considering the sun as a map. (It would be well if three observers could be appointed—each to take one fixed spot for atmospheric polarization and to note the changes which take place during totality, both in the plane of atmospheric polarization and in its intensity.)

2. The intensity of polarization should be carefully measured with the polarimeter at different parts of the corona, the observer taking care to notice when the Savart's bands disappear in the *centre* of his field, as before stated.

3. The dark moon and corona should be bisected by the line of junction of the biquartz polariscope; and the colours upon the corona should be carefully noted, not only near the line of junction, but also round the whole circumference of the dark moon. Any sudden transition from one colour to another should be especially recorded. Should any ray, or rift, or sector of colour with sharp edges be observed, it would be well to place the line of junction across such sector or rift, and note the colours upon its edges; the telescope, carrying with it the line of junction, might then be slowly withdrawn along the sector or rift from the limb of the moon outwards until all indications of the rift or its edges are lost—the observer, of course, noting the plane of polarization within the rift, and whether it differs from that of the air polarization in the neighbourhood of the sun.

SUGGESTIONS BY PROFESSOR G. G. STOKES, SEC. R.S. (*October*, 1871.) Suggestions by Professor Stokes

The chief points to which observers of polarization should direct their attention appear to be :—

A. What is the nature of the outlying corona?

B. Can the radial polarization of the circumsolar corona be traced down to the photosphere, or, if not, how low?

C. Is secondary atmospheric polarization traceable? and if so, does the plane change during totality?

A. We might suppose this to be due—

(1) to circumsolar matter (though at a great distance from the sun) reflecting light,

Suggestions by Professor Stokes

(2) to circumsolar matter in the state of self-luminous gas,

(3) to circumlunar matter diffracting and, to a certain extent, reflecting light (most improbable),

(4) to lofty atmospheric haze or cloud, of excessive tenuity, diffracting light.

The light ought to be, for

(1) strongly and radially polarized,

(2) unpolarized,

(3), (4) insensibly or all but insensibly polarized.

Hence polarization observations would only serve to discriminate between (1) on the one hand, and (2), (3), or (4) on the other.

From the faintness of the object and its considerable extent, the naked eye, armed with a polariscope, might be best. If a telescope be used, it should be of quite low power, and the aperture as large as the breadth of the pupil multiplied by the magnifying power.

Suppose the polariscope be Savart's, the quartz plates being thick enough (if the naked eye be used) to give bands as narrow as, say, 20′ diameter.

Let the observer rotate the polariscope till the bands, if any, seen on the dark moon, disappear; then, *without rotating the instrument round its axis*, let him *incline* the axis so as to point at the outlying corona in different directions round the sun, and notice whether the bands spring into existence; and if so, let him sweep *round* the sun, noticing what lies *outside* the clearly circumsolar corona of 5′ or so height, and let him notice particularly by estimation the direction, relatively to the bands, of the radius vector of the region where they are most vivid, or, better, the azimuth of both radius and bands. He should also specify, *provided he can do so with certainty*, whether the bands were black-centred or white-centred. He should also state in his account, and verify the statement by an observation made at leisure before or after totality, whether his Savart is constructed (or set) so as to have the bands *parallel* or *perpendicular* to the principal plane of the Nicol.

A very useful adjunct to a Savart's polariscope would be a glass reflector, or else a tourmaline, placed so as to cover a small segment of the field of view near the edge. On account of the possible difficulty of illuminating the reflector in the peculiar circumstances of a total eclipse, a tourmaline would seem to be preferable. It should be placed for the naked eye at the least distance of distinct vision: for a telescope, in or in front of the eyepiece, where a real image is formed so as to be seen distinctly—the axis of the tourmaline being parallel to the edge or chord of the segment, and the bands being set perpendicular to this chord. In the event of rotation during the observation, the whole should be rotated together. The question whether the bands are bright-centred or dark-centred, which in the case of slight polarization is difficult to decide, would thus be replaced by the simpler question, whether the bands in the field were of the same character as in the segment (*i.e.*, bright being a prolongation of bright, and dark of dark), or of opposite character.

The observer should previously have practised on the blue sky, rotating his Savart till the bands disappear, and noticing to what degree they are brought back by small changes of pointing

Suggestions by Professor Stokes.

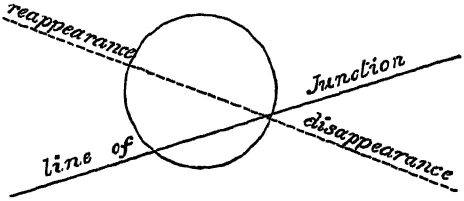
without rotation, so as to be prepared for what he is liable to from secondary atmospheric polarization during totality.

Should only very feeble bands be seen in the outer corona, such as might possibly be attributable to atmospheric polarization operating through small changes of pointing, it would be well for control to rotate the instrument *a little* till bands are fairly visible on the disc of the moon, and notice whether on passing to the outer corona, *in whatever direction*, the bands, instead of being reinforced, tend rather to be drowned in white light. Should luminous beams or dark rifts be seen in the outer corona, so as to exhibit contrast of light and shade in close proximity, a good opportunity will be afforded of testing whether the light of the outer corona s polarized or not. If it be polarized, then on rotating the Savart, so as to make the bands cut at various inclinations the boundary of light and shade, the bands will in certain azimuths of the Savart be stronger on the luminous than on the dark side of the edge of the beam or rift. If it be unpolarized, then, whatever be the azimuth of the Savart, the bands will be rather drowned in white light than reinforced on passing from the dark to the luminous side of the edge.

But Savart's and other colour-polariscopes, admirable as they are for detecting a slight polarization in light which is not particularly feeble, break down when the difficulty arises from the feebleness of the light rather than the slightness of the polarization. In such cases a simple double-image prism, with a diaphragm-tube, is better. Unless those who have seen total eclipses can decide from trial (suppose on the clear sky after sunset, or at night when illuminated by the moon), combined with their memory of the degree of illumination of the outer corona, it might be well that the observer should be provided with and should try both instruments.

B. For this a telescope will be required with a magnifying power of, say, 16 or 20. A biquartz seems the best instrument, placed at the common focus of the eyepiece (which should be positive) and objective, and combined with a Nicol's prism; or, if it can be procured, a thoroughly good tourmaline. A tourmaline might be placed over the eyehole, whereas a Nicol might have to be placed in the body of the eyepiece—which, however, is no particular disadvantage if properly done.

Let it be ascertained by previous trial how much a Nicol must be turned from the position in which the two halves are purple alike to make the tints contrast most vividly. Say it is 30°. Suppose the observer on the line of central shadow, so that the limits of disappearance and re-appearance will be on opposite ends of a diameter. The biquartz and Nicol having been relatively set so that the line of junction is in the plane of polarization of light extinguished by the Nicol, turn them together before totality 30° (or whatever other angle may have been fixed on) to either side of the diameter of disappearance, and, pointing the telescope to the place of disappearance, await totality without dazzling the eye. The moment the sun is covered, apply the eye to the telescope, and notice whether there is a vivid contrast of colour right and left of the line of junction of the quartz plates *all the way down to the dark moon*, or only in the higher parts of the circumsolar corona.



Suggestions by Professor Stokes.

Be ready to repeat the observation before reappearance, with the telescope pointed to the place of reappearance; and meanwhile, if time permits, repeat PRAZMOWSKI's observation by pointing the telescope, without rotation of the analyzer, so that the line of junction bisects the moon, and noticing whether the semicircles of the corona are purple alike where they abut on the junction, and what is the order of colours in the semicircle on receding from the junction. A record as to which is which of the two halves of the biquartz should be carefully preserved.

Should secondary atmospheric polarization be so strong as to throw doubt on the results (which may be judged of by noticing the light on the dark moon), it would be well to rotate the analyzer till the two halves seen on the dark moon are purple alike, and then alter the pointing of the telescope and repeat PRAZMOWSKI's observation.

It will be observed that the same general principles apply to the elimination of atmospheric polarization, whether the polariscope employed be a Savart's polariscope, a polariscope with quartz wedges, or a biquartz polariscope.

C. This is of little intrinsic interest, its chief use being to clear up possible doubts as to the results obtained by the observers of A and B. Should there be an observer not otherwise employed, he might be deputed to observe the direction of the Savart's bands on disappearance, both on the dark moon and the surrounding sky, and whether this direction changes during totality. Also it should be specified in which pair of opposite quadrants they were black-centred and in which white-centred. Should this be found impossible or uncertain (the instrument being unprovided with the adjunct mentioned above), the Savart might be used as a simple Nicol by turning it end for end, so that the quartz plates are next the eye; and with this the plane of polarization might be roughly determined by means of the azimuth of the principal plane of the Nicol when the light most nearly disappears.

Should registration of the azimuth be attempted, the Savart would be fixed so as not to be reversible. In that case the observer might be provided with a double-image prism and diaphragm-tube for separate use in case of need.

Stoppage of Stray Light in a Telescope designed for Polarization.

The want of this appears to have occasioned some difficulty at the last eclipse.

The simplest way is by a stop, with a hole just large enough to contain the image of the object-glass. Such exists in the erecting eyepiece, where an image of the object-glass is formed in the body of the eyepiece. It exists, too, in a Gregorian or Cassegrainian telescope, where the stoppage is imperative. But in an ordinary refracting telescope, with an inverting eyepiece, the eyehole (from certain motives of convenience) is larger than and in front of (*i.e.* nearer the object-glass than) the bright circle, or image of the object-glass; and unless the tube is sufficiently provided with stops, when a faint object near a bright one is looked at, light from the bright object, reflected from the inside of the tube, is liable to enter the field of view. Large instruments are provided with stops; but I fancy smaller instruments are sometimes turned out without them. This should be looked to.

The observer may test the correctness of stopping by taking out the eye-piece, inserting a paper disc with a central hole of the size of the field-glass, turning the instrument nearly but not quite to a bright object, as well as to points more distant from the bright object, and

noticing whether the side of the tube, even when viewed in a direction grazing the edge of the hole, is properly dark, so that only the edges of the stops are seen.* On the other hand, the stops should not obstruct a clear view of the object-glass as seen through the hole representing the field-glass, or they will render the outer portions of the object-glass useless. Suggestions by Professor Stokes.

General Remarks.

I consider the observation recommended by Mr. RANYARD (see above, No. 3), "The dark moon . . . . be especially recorded," very important, IF, after what PRAZMOWSKI and RANYARD have done, the point be still deemed doubtful. PRAZMOWSKI's observation seems to have been beautifully devised and executed, but carelessly described. It is only by conjecture that I can make sense and harmony with what is known out of his observation as described by himself. But I think Mr. RANYARD has at least shown that our conjectural interpretation of PRAZMOWSKI's observation is the right one, and if so, the point seems settled.

It was for this reason that, in lieu of No. 3, first half, I proposed something new. What becomes of the magnesium, etc., which the spectroscope reveals low down in the gigantic puffs which the sun emits? The hydrogen must surely carry the magnesium, etc., with it to the higher regions, though the magnesium, etc., would soon be condensed, and so would not be detected by the spectroscope. These substances would exist in the form of an excessively fine haze or dust. I use the two words, "haze" to denote a filmy cloud of molten, "dust" of solid matter. This haze or dust is capable of detection, and, according to my interpretation, *has* been detected, by polarization; and it is interesting to know how low down it can be detected. Mr. STONEY's speculations as to layers are utterly inapplicable here, as they imply a state of tranquillity quite unlike what we now know to exist, at any rate in connexion with the puffs.

SUGGESTIONS BY PROFESSOR E. C. PICKERING.

Professor E. C. PICKERING, at the end of his report printed in the U. S. Coast Survey Report for 1870, Appendix No. 16, p. 60, makes the following suggestion:— Suggestions by Prof. Pickering.

"I have one other suggestion to make for future observations, namely, placing at the diaphragm of a large portrait camera a double-image prism,† and strapping it to a telescope mounted equatorially; we should thus obtain a permanent record of two images of the corona, one polarized horizontally, the other vertically; if they were polarized radially, the former would be comparatively faint above and below, the other on the sides. Since the two images would be in other respects precisely alike, we should have an excellent means of permanently recording any polarization of the corona while that of the sky would be neutralized."

* (Note by Prof. STOKES): If reflexion occurs from the part of the tube so near the eye as not to appear *within* the field, it will not signify much.

† Dr. H. VOGEL, of Berlin, who joined the party of the English Eclipse Expedition of 1870 that stationed itself upon the slope of Mount Etna, had provided himself with a camera and double-image prism for the purpose of obtaining photographic evidence of the coronal polarization; but unfortunately the Etna party were enveloped in cloud during the period of totality, and no photographs could be obtained.

CHAPTER XLIII.

SPECTROSCOPIC OBSERVATIONS.

THE history of the spectroscopic analysis of the light of the solar surroundings may be said to commence with the observations made during the Eclipse of 1868. Up to that time a few observers had made use of prisms during eclipses; but it seems doubtful whether the light they examined was that of the corona and prominences, or whether it was derived from the clouds and sky in the neighbourhood of the eclipsed sun.*

Fusinieri's observation.

FUSINIERI, MAGRINI, DUNKIN and BARREDA'S observations all seem to have been made with prisms without slits. FUSINIERI may possibly have seen detached images of the chromosphere corresponding to the C, D_3, and F lines; but his observation is very imperfectly described—and if the above conjecture be the true explanation of his observation, it is certain that he did not know how to interpret what he had seen, and that the gaseous nature of the prominences remained unrecognised till the observations of 1868.†

Partial phase observations.

During the partial phases of a solar eclipse, until the last few seconds before totality no difference is perceptible in the spectrum of the light

* It has been shown in a former chapter that the light of the sky within the area of totality is chiefly derived from the belt of clouds upon the horizon which are illuminated by the uneclipsed solar crescent: we should therefore expect to find the spectrum of light derived from the sky or clouds within the area of totality similar to the ordinary solar spectrum, though perhaps somewhat modified by the long course of the rays through the lower parts of our atmosphere.

† Although not strictly a spectroscopic observation, we have given amongst these earlier observations a description of the colour of the prominences as seen by Prof. POLE, who was colour-blind for the red end of the spectrum. His description of his sensation of colour, or rather absence of colour, in the light of the prominences was sufficient to have proved that the prominences do not resemble the rose-tinted clouds seen in our own atmosphere at sunset; but although his observation was referred to in several magazine articles describing the eclipse of 1860, this want of analogy does not seem to have been recognised.

derived from the solar crescent. FORBES, as early as 1836, observing probably with some form of integrating spectroscope, satisfied himself that the spectrum from the thin solar crescent did not differ materially from the ordinary solar spectrum; but it will be seen that the deduction which he drew from his observation was unwarranted, and that if during a total eclipse he had continued his observations until the commencement of totality (the eclipse of May 1836 was annular), he might have observed a very marked change in the character of the spectrum.

In considering the spectroscopic observations which have been made during totality, we shall (since the spectrum of the chromosphere can be studied at leisure with an uneclipsed sun) not devote space to a discussion of the spectra of prominences which have been seen during total eclipses, but shall confine our attention to observations bearing upon the spectrum of the corona and upon the spectrum of the lower parts of the chromosphere, which can be studied under exceptionally favourable conditions during the first and last few seconds of totality.

Spectrum of the lower parts of the chromosphere.

First as to the spectrum of the lower parts of the chromosphere, YOUNG, observing in 1870 with the slit of an analyzing spectroscope, placed tangentially to the limb of the sun at the point where the last ray was about to vanish, saw the ordinary solar spectrum gradually fade away; and "all at once, as suddenly as a bursting rocket shoots out its stars, the whole field of view was filled with bright lines." His observation was confirmed by PYE, who was observing at the same station with an integrating spectroscope; and BURTON and NOBILE, who were observing in Sicily, noted the one about twenty-five and the other not less than forty bright lines in the spectrum of the cusps of the thin solar crescent.

In 1871 the bright lines at the cusps were seen by both MACLEAR and HERSCHEL. FYERS, observing with an integrating spectroscope, saw the reversal of the lines at the beginning of totality; and RESPIGHI seems to have seen the reversal at the end of totality, though he failed to observe it as totality commenced. It will be seen that he was observing without a slit; and it is possible that at the beginning of totality irradiation from the bright images of the reversing layer may have obliterated the dark interspaces, while at the end of totality, when the sensitive condition of his eye was improved, the dark interspaces may have been more easily detected.*

* It is possible also that the reversing layer on the east limb may have been brighter, and

At the annular eclipse of 1872 POGSON observed the reversion of the lines on the formation and again at the breaking up of the annulus. And in 1874 STONE again confirmed the observation of YOUNG.

Duration of bright line spectrum.

The observers differ greatly as to the length of time during which the bright lines have remained visible. Their estimates vary from one-eighth of a second to as much as seven seconds: intervals of time which would correspond to depths of the reversing layer ranging from about one-sixteenth of a second of arc to as much as three-and-a-half seconds of arc—or, speaking roughly, from about thirty miles to as much as 1500 miles in thickness, thus:—

Time during which the bright lines have remained visible.

1870.	Pye	. . . . .	less than one-eighth of a second.
	Young	. . . .	2 seconds.
1871.	Fyers	. . . .	$1\frac{1}{2}$ or 2 seconds.
1872.	Pogson	at first internal contact.	less than 2 seconds.
		at second internal contact.	5 to 7 seconds.
1874.	Stone	. . . .	about a second.

NOBILE noted that the bright lines at the cusps were visible at least

consequently the irradiation of the images greater, than at the west limb. The varying heights of the prominence lines seen under ordinary conditions would lead us to suppose that the height and intensity of the lines from the lower parts of the chromosphere (commonly termed the reversing layer) would not be uniform at different parts of the sun's limb.

The assumption that the reversing layer was brighter on the east than on the west limb during the eclipse of 1871 is favoured by the fact that the reversal of the lines was noted by FYERS with his integrating spectroscope at the beginning of totality; but it does not seem to have been seen by him at the end, although in the meantime he had increased the breadth of his slit.

Possibly something may be learnt from the eclipse photographs as to the brightness of the chromosphere at different parts of the sun's limb. The image of the moon in the photographs taken during totality is found upon measurement to be more elliptical than can be accounted for even when due allowance is made for the moon's motion during the exposure. In the case of photographs taken soon after the beginning or just before the end of totality, this ellipticity can no doubt be explained by increased irradiation due to the brighter light of the lower depths of the chromosphere exposed on the east or west limbs. But undue ellipticity is also to be found in photographs taken at mid-eclipse, which it would seem can only be accounted for by supposing that the chromosphere is brighter at an equal height in equatorial than in polar regions. The difference between the irradiation in equatorial and polar regions is more easily perceived in the photographs of the 1869 and 1871 eclipses than in the photographs of the 1870 eclipse. See a letter to *Nature*, vol. ix., p. 103.

five minutes before and after totality, and MACLEAR that they were visible about "three minutes before middle eclipse."

Various changes in the solar spectrum observed just before totality.

HERSCHEL in 1868, observing the spectrum of the solar cusps a few minutes before totality, recorded "an increasing brilliancy in the spectrum in the neighbourhood of D"; and SECCHI in 1870, observing the spectrum of the cusps three or four minutes before the beginning of totality, thought that the Fraunhofer lines appeared more marked, broader, and more nebulous than under ordinary circumstances; but neither of these observations appear to have been confirmed by other observers.

ABBAY in 1870, observing with an integrating spectroscope, saw as totality commenced "the dark Fraunhofer lines slowly disappear, leaving a dull spectrum, which also faded away." And RESPIGHI in 1871, at the beginning of totality, observing without a slit, says a few seconds before totality the dark lines "disappeared completely, and the spectrum became continuous," without exhibiting the reversal of the lines, for which he was intently watching.

Evidence as to the bright lines corresponding with the dark lines of the solar spectrum.

Some of the conspicuous Fraunhofer lines have not been seen reversed in the spectrum of the chromosphere,* and others are but rarely seen reversed. It becomes, therefore, an interesting question to examine what evidence there is to show that all the dark lines of the solar spectrum have been seen reversed at the beginning or end of totality.

YOUNG thought that the bright lines seen by him corresponded with the ordinary Fraunhofer lines, and he remarks that though "it would be very rash on the strength of such a glimpse to assert with positiveness that these innumerable lines corresponded exactly with the dark lines of the spectrum," yet the general appearance of the spectrum and the "grouping of the lines seemed perfectly familiar" † to him. PYE, in describing the

* See Young's catalogue of bright lines seen in the spectrum of the chromosphere, given in the *American Journal of Science and Arts*, Vol. IV., Nov. 1872.

† A cursory examination of Young's catalogue will show that if all the chromosphere lines which have been seen reversed under ordinary circumstances are plotted down with thicknesses corresponding to their relative brightness, or to the frequency numbers given by Young, the general appearance of such a map of the chromosphere spectrum will differ materially from the general appearance and grouping of the Fraunhofer lines. The relative brightness of the lines at any depth of the chromosphere would not, however, necessarily correspond either with such a map or with the relative intensity of the Fraunhofer lines.

bright lines, says that the effect was "as if all the dark lines were converted into bright ones."

RESPIGHI remarks that he "could not determine whether the bright lines seen by him at the end of totality were due to a general or partial reversal of the solar lines, or to a simple discontinuity of the spectrum, since they were too soon immersed in a flood of light."

FYERS says that "the dark lines suddenly changed to intense brilliancy."

POGSON writes that he "saw all the dark lines reversed and bright."

STONE is more careful, and adds, "My impression was that all the Fraunhofer lines were reversed; but this is, of course, only an impression. I can only state as a matter of fact that a very large number of bright lines were seen."

It is especially worthy of remark that the line which appeared to POGSON to be the most brilliant of the bright lines seems to have corresponded in position with B, a marked Fraunhofer line which has not been seen by YOUNG as reversed in the spectrum of the chromosphere.

During the five or seven seconds that the bright lines remained visible at the second internal contact, POGSON placed the cross-wires of his micrometer upon the line, and on afterwards examining the position of the wires, he says that "the reading clearly showed that the line was B."

Bright line spectrum seen during the first or last few seconds of totality.

1870.	**Pye.**	Integrating spectroscope. At the first instant of totality a great number of bright lines were seen,—the effect being as if all the dark lines of the spectrum were converted into bright ones. The duration of the bright lines was estimated at less than one-eighth of a second.
	Young.	Analyzing spectroscope of great dispersive power; slit tangential at E. limb. The ordinary solar spectrum gradually faded away, and suddenly the whole field of the spectroscope was filled with bright lines more numerous than could be counted: as far as could be judged, the grouping of the lines appeared to correspond with that of the Fraunhofer lines. All the bright lines faded away in about two seconds.
	Burton.	Analyzing spectroscope. Just before totality about twenty-five lines made their appearance in the chromosphere at the lower horn.
	Nobile.	Analyzing spectroscope. For at least five minutes before and after totality not less than forty bright lines seen at the cusps.
1871.	**Maclear.**	Analyzing spectroscope. About three minutes before middle eclipse,

slit radial to cusp, *b* E, and apparently all the iron lines became bright. The cusp was watched for two minutes, during which time the bright lines were very distinct, and increasing in number. The slit was then moved, and placed tangentially at the east limb. The number of bright lines increased till the spectrum was full of them. They remained for an instant, and then vanished. (Mr. Lockyer looked through Captain Maclear's instrument, and confirms his observation with regard to the bright lines seen at the cusp.)

Herschel. Analyzing spectroscope. Just before totality slit at cusp (*query*) numerous, but not very many bright lines of various intensity and considerable length were observed. At the end of totality slit placed tangentially at the west limb; a number of bright lines seen. The field began to brighten, and immediately the number of bright lines increased so greatly that to attempt to record them was hopeless.

Respighi. A prism of small angle placed in front of the object-glass of a telescope. A few seconds before totality the principal dark solar lines disappeared completely, and the spectrum became continuous. The reversal of the Fraunhofer lines was however not seen, although it was watched for intently. At the end of totality bright lines separated by dark spaces were seen; they were soon immersed in a flood of light.

Fyers. Integrating spectroscope. Just before totality the dark lines suddenly changed to intense brilliancy. Their brightness only lasted for about a second and a half or two seconds, when they disappeared suddenly.

1872. **Pogson.** Annular eclipse: analyzing spectroscope. At the first internal contact all the dark lines seen reversed and bright—for less than two seconds. Again, at the second internal contact, the reversion of the lines was seen lasting from five to seven seconds. The micrometer wires were placed upon the most brilliant line of all: it turned out to be B.

1874. **Stone,** Analyzing spectroscope, slit placed tangentially at the east limb. At the instant of totality the field appeared to be full of bright lines of different lengths. They vanished after about a second.

Spectroscopic Observations of the Light of the Corona.

We will first give a short sketch of the chief steps which have been made at successive eclipses in our knowledge of the spectrum of the light derived from different parts of the coronal area, and will then proceed to examine in detail the evidence for and against the various conclusions which have been arrived at.

In 1868 Rayet, while observing the spectral lines of the great horn-shaped prominence with the slit of his spectroscope radial to the sun's

limb, noticed that the bright lines which he identified with D, E, and F, extended to a greater height than the other prominence lines. On the side of the spectrum corresponding to the moon's limb all the lines were sharply cut off, but on the other side these three lines were continued "par un trait lumineux très-faible" to a height equal to about double that of the other prominence lines. From Rayet's description it would appear that the other prominence lines corresponded in height with the prominence, and that therefore F, E, and D—or to speak more accurately, F, 1474, and D_3 (or more probably C)—were traced by him to a height of more than 6′* above the sun's limb. RIBA, TENNANT, and POGSON, in 1868, all using analyzing spectroscopes, describe the spectrum of the corona as continuous without either bright or dark lines; but they do not give the height above the sun's limb of the part of the corona from which the light they were examining was derived, nor do they give any particulars from which the height may be determined. HERSCHEL, on the other hand, reported that "no trace of continuous spectrum" was to be seen.

In 1869 HARKNESS found the spectrum of the corona to be continuous, and about as bright as that given by the full moon on a clear night. The spectrum was crossed by one bright line, the position of which he registered by means of a recording spectroscope, and afterwards found to correspond with 1497. Judging from a diagram given by EASTMAN, who assisted HARKNESS in his observations, the slit of the spectroscope at the time of this observation cannot have been as much as 5′ from the limb of the sun. YOUNG also found a faint continuous spectrum crossed by one † bright line, the position of which he identified as corresponding exactly with the dark line 1474. But he did not trace the height to which this spectrum could be perceived, though he remarked that on moving his slit away from a prominence, 1474 remained visible while the other prominence lines disappeared. He adds in a note that he could not recall with certainty whether 1474 "retained its brilliance at any considerable distance from the prominences, or only in their immediate neighbourhood."

* Mr. DE LA RUE, in his paper "On the Solar Eclipse of August 18th, 1868," gives the height of the Great Horn, as measured upon Col. Tennant's photographs, as 3′ 22″ above the sun's limb. *See a note on p.* 76 *of vol.* xxix. *of the "Monthly Notices."*

† He also speaks doubtfully as to whether the bright lines whose position he gives as 1250±20 and 1350±20 extended across the field.

PICKERING also, using an integrating spectroscope, observed a continuous spectrum "with two or three bright lines—the brightest in the neighbourhood of E:" an observation which enabled YOUNG to predict that the 1474 line he had observed must belong to the corona, and be derived from a considerable area,*—for as seen by YOUNG with his analyzing spectroscope, 1474 was not as bright as C or D_3.

In 1870 YOUNG again identified the green coronal line as corresponding to the dark Fraunhöfer line 1474; he traced it in various directions from the solar limb, and found it extending rather further to the east and west than in the neighbourhood of the sun's poles.† He also traced the bright lines C and D_3 to a height of 4′ or 5′ from the east limb, but concluded that the extension of these latter lines above the prominence area was due to the presence of haze or thin cloud, as they were also to be observed upon the disc of the moon. CARPMAEL found a green line and two other bright lines at a height of at least 8′ above the sun's limb. HARKNESS traced the green line to a height of 10′ or 15′ above the sun's limb; and WINLOCK traced the bright lines 1474, D_3, and the hydrogen lines C and F, to a height of 25′ above the limb. But the value of CARPMAEL's, HARKNESS', and WINLOCK's evidence as to the extent of the bright line area is materially diminished by the fact that their observations were made through passing clouds. MACLEAR, observing through cloud, saw bright lines when his slit was at the centre of the moon's disc. NOBILE, in 1870, found that the green coronal line was so brilliant that it could be seen with his analyzing spectroscope of one prism for about fifteen seconds after the end of totality; and ABBAY and PYE, both observing with integrating spectroscopes, found that 1474 was the brightest of the lines observed.

In 1871 the 1474 area was traced to a height of 6′ or 7′ by RESPIGHI, 7′ by LOCKYER, 10′ by JANSSEN, at least 10′ by HERSCHEL and TENNANT,‡

* See the note to Prof. Young's account of the eclipse, in the *American Journal of Science and Arts* for Nov. 1869.

† To the east he found it extending rather "more than the sun's radius, or about 16′; to the west 13′, to the north 12′, and to the south 10′."

‡ The height to which the 1474 line was traced by Herschel and Tennant is rather doubtful: on the western limb it was not visible when the slit was placed at a height of 16′; but during their third observation the southern end of their slit (which was 18′ long) must have been at least 20′ from the limb,—and Herschel speaks of the line as extending all across the field.

and 22′ by MOSELEY. The hydrogen spectrum was traced to a height of 2′ by LOCKYER, 6′ or 7′ by RESPIGHI, and 10′ by JANSSEN.

HERSCHEL observed that the 1474 line extended without interruption into the area of the great southern rift; and JANSSEN noticed that it appeared to be interrupted in the spectrum of a prominence which he examined with his slit radial to the moon's limb. The hydrogen lines, which were very bright in the spectrum of the prominence, were prolonged upwards into the region of the corona; but the 1474 line was lost in the part of the spectrum corresponding to the prominence, while it was bright in the region of the corona. JANSSEN also mentions that he observed dark lines in the continuous spectrum of the corona. One of them he identified with the dark line D, and he speaks of other dark lines in the green.

In 1874 STONE saw in the spectrum of what he describes as the inner corona the hydrogen lines, 1474, and two or more much fainter bright lines of less refrangibility. There was also a continuous spectrum, which he speaks of as rich in red light. During a hasty examination he observed no dark lines in the spectrum of the inner corona. The height of the inner corona is not given; but from the drawing he refers to it would appear that he speaks of an area extending to a distance of at least 7′ from the sun's limb. In the outer corona, extending to a distance of some 45′ from the sun's limb, STONE observed the bright line 1474 and a continuous spectrum crossed by dark lines.

Identification of the Bright Lines seen in the Spectrum of the Corona.

A glance at Plate I. at the end of the volume will assist the reader in forming an estimate of the evidence which exists with regard to each of the lines of the coronal spectrum. Plate I., part 1, is constructed from the descriptions of observers who have made use of analyzing spectroscopes. Plate I., part 2, is constructed from the descriptions of the observers who have made use of integrating spectroscopes.

Position of the green line in the spectrum of the corona.

RAYET in 1868 gave the position of the green line as E.; HARKNESS, in 1869, making use of an illuminated scale for reading the position of the lines, gave its place as corresponding with 1497 of Kirchhoff's scale; and HERSCHEL in 1871 gives the same reading. Herschel's observation was made with a registering spectroscope, by means of which the positions of

the lines were pricked off upon a register-card. YOUNG, in 1869, fully satisfied himself that the line corresponded with, and was the reversal of the Fraunhofer line 1474. In 1870, CARPMAEL, from a hasty measurement made with a cross-wire micrometer, gave the position of the green band or line as "about 1359," but his observation was interrupted by clouds before he had time to bring the cross-wires to the centre of the band. ABBAY more leisurely placed the cross-wires of his micrometer upon the bright line, and after the eclipse was over found that the centre of the wires was on the vacant space between the lines 1464 and 1494. WINLOCK, with a recording spectroscope, and coarse cross-wires in the field of view, registered the place of the green line as "a little more refrangible than Kirchhoff's 1474," but he adds that the difference of the reading was perhaps not greater than, under the circumstances, could be attributed to an error of observation. BURTON, who observed the eclipse through passing clouds, gives the position of the line from a hastily-made estimate as "a little less refrangible than E." DENZA estimated its position to be between 1463 and 1467. HARKNESS had not time to determine the position of the line before his light was blown out, but he saw that it was not far from the place of 1474 of Kirchhoff's scale. LORENZONI, making use of an illuminated scale in the field of his spectroscope, gave the position of the green line as 1463. And NOBILE says that it probably corresponded with 1474.

SAXTON, in 1871, carefully placed his cross-wires before the eclipse began in the position due to 1474, and during totality observed that the cross-wires "appeared to intersect the bright line truly." FYERS, with a recording spectroscope, pricked off three times the positions of the lines, and found that the marks on his register-plate corresponding to the green line agreed approximately with the place of 1474. STONE, in 1874, making use of a star spectroscope, with two prisms of 60° of dense flint glass, made a careful bisection of the green line of the corona with his micrometer wire, and after the eclipse was over found the wave-length "to be 5312," which differs about the breadth of the D lines from 1474.*

* The wave-length of 1474 is given by ÅNGSTROM as 0·0005316 millimetres. The wave-length of the chromosphere line would appear, from the diagram given by YOUNG in his "Note on the Duplicity of the 1474 Line," to be about 0·000531595 mm., and the wave-length of the

But the most accurate comparison of the position of the green line of the corona with the position of the 1474 chromosphere line was made by YOUNG in 1870. His observation was made with a spectroscope the dispersive power of which was equivalent to thirteen prisms of 55°. Just before totality he brought the cross-hairs of his micrometer up to the 1474 chromosphere line, which was already bright, and having accurately bisected the line, he left the micrometer in position until totality, when he found that the green line of the corona, to a distance of 16′ from the sun's limb, was accurately bisected. His own estimate of the possible error of his observation is that it could not exceed one-tenth of a division of Kirchhoff's scale. He has since found that the green line of the chromosphere spectrum does not accurately coincide with the Fraunhofer line 1474. In a paper in "The American Journal of Science and Arts" for June 1876, Prof. YOUNG says that as early as 1870 he had suspected that the bright line 1474, as seen in the chromosphere, was slightly more refrangible than its dark analogue. The bright line seemed to fall slightly below—that is, on the more refrangible side of the dark one—but he felt that he had not sufficient evidence to warrant such an assertion; more recently, however, he has succeeded in proving that the Fraunhofer line 1474 is unmistakably double, the two components being separated by a distance equal to about one-fortieth of the distance between the D lines. The more refrangible component is slightly winged or hazy at the edges, while the other is narrower and better defined.* The more refrangible of the two lines matches with the chromosphere line, and the other belongs to the spectrum of iron. Accepting Prof. YOUNG's estimate as to the possible error of his observation in 1870 with regard to the identity of the chromosphere and corona lines, we see that the identity of the corona line with

adjacent iron line to be about 0·000531605 mm. The wave-lengths of the D_1 and D_2 lines, as given by ÅNGSTROM, are D_1 0·00058950 mm., and D_2 0·00058890 mm.

* Prof. YOUNG's observations have been made with a diffraction grating of 8640 lines to the inch, prepared by his friend Mr. RUTHERFORD. By placing a prism in front of the object-glass of the viewing telescope, with its refracting edge perpendicular to the lines in the grating, the spectra of the different orders are seen ranged one above the other. Thus the red of the sixth order is seen below the yellow of the seventh, and this, again, underneath the green of the eighth, and so on. The difficulty caused by the overlapping of the spectra of the higher orders is by this method obviated, and Prof. YOUNG has thus succeeded in studying the Fraunhofer lines as seen in spectra of the eighth and ninth orders.

the more refrangible of the two Fraunhofer lines still requires further confirmation. One-tenth of a division of Kirchhoff's scale about corresponds to one-fortieth of the distance between the D_1 and D_2 lines, or to the distance between the two components of the 1474 Fraunhofer line.

Considering the faintness of the corona line, and the great dispersion necessary for such an accurate observation, as well as the fact that a velocity of less than five miles a second of the matter of the chromosphere to or from the observer would account for a similar displacement, there seems no great prospect that the identity of the corona line with the more refrangible of the two 1474 Fraunhofer lines will be established at future eclipses with very much greater certainty than has at present been attained to.

The spectrum of hydrogen.

The hydrogen lines of the coronal spectrum also seem to be satisfactorily identified. JANSSEN, in 1871, observing with a direct-vision spectroscope of ten prisms, could not detect any difference in the place of the hydrogen lines of a prominence and the corresponding lines of the corona. On placing his slit radially to the moon's limb, so as to cut a prominence and extend out into the area of the corona to some 7′ or 8′ from the limb, he noted that the principal lines of the protuberance were prolonged upwards into the part of the spectrum corresponding to the corona; and he considered that his observation definitely proved the existence of hydrogen in the corona. RAYET also, as early as 1868, observed the F line of a prominence extending up into the area of the corona. MACLEAR, WINLOCK, and YOUNG, in 1870, observed some of the lines of the hydrogen spectrum from the area of the corona, but it seems to be doubtful whether the light they examined may not have been derived from the prominences after having been dispersed by the particles of passing clouds.

LOCKYER and RESPIGHI in 1871, and STONE in 1874, all three observing with a clear sky, satisfied themselves of the existence of hydrogen in the lower parts of the corona, but they only appear to have identified the lines from their general knowledge of the hydrogen spectrum.

D_3 not present in the spectrum of the corona.

The D_3 line, which is known to be very brilliant in the spectrum of the chromosphere, is given by most of the observers using integrating spectroscopes. WINLOCK in 1870, using an analysing spectroscope, observed

the line* at a distance of at least 12′ from the limb; and YOUNG observed it to a distance of 4′ or 5′; but both these observations were made through passing cloud, and as the line has not been seen in the spectrum of the corona by other observers † using analyzing spectroscopes, we must conclude that its presence at these altitudes was due to dispersion by clouds. YOUNG, 1870, was of opinion that it was not a corona line, as he found it extending "even upon the disc of the moon"; and MACLEAR, 1870, who found the D line at an altitude of 8′, also found it at the centre of the moon's disc.

Faint lines in the spectrum of the corona less refrangible than 1474.

YOUNG, observing in 1869, says that he had an impression that the two faint lines whose position he gives as 1250 ± 20 and 1350 ± 20 extended all across the field of view of his spectroscope, in the same manner as the 1474 line. When, however, he had an opportunity of observing the spectrum of the corona again in 1870, he found no other bright line in its spectrum besides 1474. But in weighing this negative evidence we should remember that YOUNG's observation in 1870 was made through clouds and flying wrack,‡ and that he describes the 1250 and 1350 lines observed by him in 1869 as very faint. PYE, in 1870, observing with an integrating spectroscope, speaks of a "small line near 1474, nearer than it to the red," which appeared for an instant, but could not be seen again. In answer to some interrogatories by Prof. YOUNG, he explained that it was just at the close of totality when the line was looked for again and could not be found,—an observation which would seem to indicate that the line was not due to the lower parts of the chromosphere, which would then be uncovered. Its appearance for an instant, and subsequent disappearance, may possibly be explained as having been caused by the passing clouds through which the observations were made. DENZA, in 1870, observing through cloud, saw in the spectrum of the corona—besides the bright green

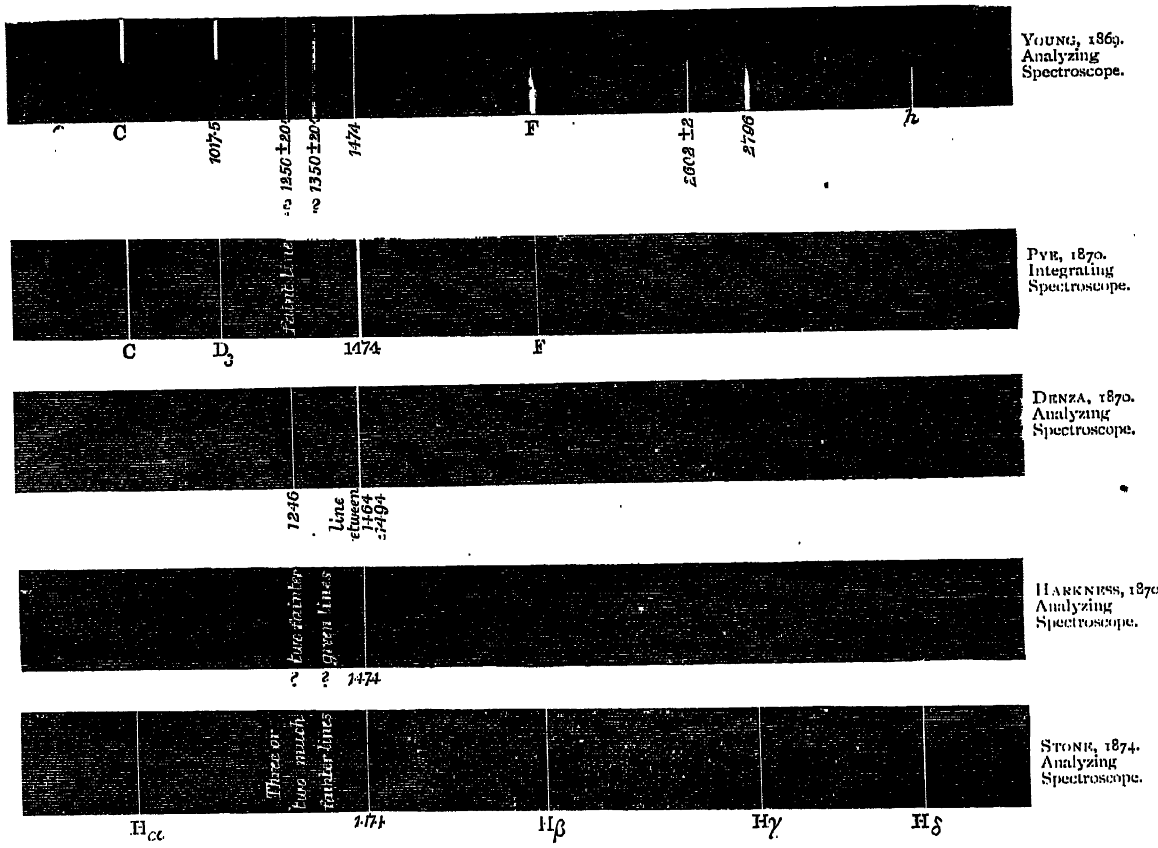
* WINLOCK speaks of the line as being near D, and a little *less* refrangible than the sodium line by a difference greater than he could have supposed the error of the observation would be.

† We have not referred to RAVET's observation in 1868, as it seems probable that the prolongation of the D line he speaks of really refers to the C line. If the F line of the hydrogen spectrum were seen prolonged, the C line, which is much more brilliant, would certainly be seen extending to an equal altitude.

‡ ABBAY, observing close to YOUNG at Jerez, says, "There was a great amount of cloud and wrack flying, and it was only through a rift in the cloud that I obtained a view of the corona." WINLOCK, also observing at Jerez, says that he and Mr. ALVAN CLARK were obliged to "seize every opportunity offered by openings among the clouds."

line 1474—another less brilliant line in the yellow, whose position he gives, from an estimate of its place made immediately after totality, as about 1246 of Kirchhoff's scale. Harkness, also observing through cloud, in 1870, speaks of having seen two green lines fainter than 1474, and of a less degree of refrangibility, which he was pretty confident belonged to the corona. And Stone, observing in 1874, speaks of "two or more lines" much fainter than 1474, and of less refrangibility, which he saw in the spectrum of the inner corona.

The state of the evidence with regard to the faint lines (other than



1474) which have been observed in the spectrum of the corona, will probably be more easily appreciated by referring to the woodcuts of spectra given above. We have made no reference to the observation of Ferguson in 1871 as to the three lines between 1474 and D, nor as to the line slightly more refrangible than 1474: the lines between 1474 and

D were only observed just before the end of totality, and consequently probably belonged to the lower parts of the chromosphere. For the same reason we have not referred to the observation of MOSELEY in 1871, who speaks of two faint green lines close together, which he saw "flash in between 1474 and D, and then disappear." His observation was made during the first ten seconds of totality, when his slit was tangential to the east limb.

Continuous Spectrum of the Corona.

IT will be seen that RIHA, TENNANT, and POGSON in 1868, WINLOCK in 1869, BROWN and (query) PERRY in 1870, all describe the spectrum of the corona as continuous, without bright lines; while HERSCHEL * in 1868, ABBAY in 1870, and FERGUSON and MOSELEY in 1871, state that no continuous spectrum was visible.

RAYET in 1868, HARKNESS, PICKERING, and YOUNG in 1869, MACLEAR, HAMMOND, ABBAY, PYE, WINLOCK, YOUNG, BURTON, DENZA, HARKNESS and LORENZONI in 1870, LOCKYER, JANSSEN, HERSCHEL, RESPIGHI and FYERS in 1871, and STONE in 1874, all speak of the spectrum of the corona as consisting of bright lines seen on a more or less faintly illuminated background.

Brightness of the continuous spectrum.

HARKNESS, in 1869, describes the continuous spectrum as about as bright as that given by the full moon on a clear night; and BROWN in 1870 speaks with great appearance † of accuracy of the continuous spectrum of

* HERSCHEL's observation appears to have been made through passing clouds; and no doubt the continuous spectrum of the corona would be more easily lost under such circumstances than the bright lines of the great prominence he was examining. ABBAY's observation at Jerez was also made through cloud.

FERGUSON and MOSELEY, who both observed at Pulmotte, were using, the one an integrating spectroscope, and the other an analyzing spectroscope of five prisms. The sky at Pulmotte appears from other accounts to have been quite clear, and we are unable to suggest any reason that will account for their having both failed to observe the continuous spectrum.

† No photometric comparison seems to have been made, and it should be remembered that a change in the breadth of the slit would entirely alter the brightness of the spectrum observed. The different circumstances, also, under which the two spectra would be seen, would greatly bias the mind in making such a comparison. Lieutenant BROWN's observation must have been made in a very hurried manner, for he describes himself as having found time during totality (which only lasted 2 m. 8 s.) to examine the spectrum of the corona at five (query ten) points, the height of which he gives to half-minutes of arc; he also examined the spectrum of the light derived fron the area of the great rift, and gives the position of the lines in the

the corona, as being "about equal in intensity to that given by the moon before entering its third quarter." PICKERING, in 1869, using a small integrating spectroscope, says that the continuous spectrum was bright enough to leave its upper and lower edges well defined. WINLOCK in 1870, making use of an analyzing spectroscope with two prisms, found that there was no difficulty in seeing the cross-wires of his micrometer; and HERSCHEL, in 1871, observing with an analyzing spectroscope with one compound prism, says that he had a distinct recollection of a dimly illuminated field in which he could see the needle easily.

We are not aware of any observations which would enable us to compare the amount of light due to the continuous spectrum of the corona with that due to the bright-line spectrum, but the remarks of some of the observers would lead us to conclude that the light derived from the continuous spectrum is by no means inconsiderable. RIHA mentions that he had seen the more conspicuous Fraunhofer lines with much fainter spectra;* and other observers, as will be seen, mention the continuous spectrum as showing distinctly recognizable traces of colour. LOCKYER says that he was astonished at the vividness of the continuous spectrum; and STONE speaks of a "pretty bright spectrum" from the inner corona, "which appeared continuous." On the other hand, some observers describe the continuous spectrum as very faint: thus POGSON, in 1868, speaks of it as "a faint light scarcely coloured," † and RAYET describes the bright lines as seen "sur un fond uniforme presque noir." FYERS also, in 1871, says

spectrum of three prominences. Besides this, he appears to have found time to examine the corona with the naked eye, for the purpose of making the detailed drawing of the outline of the corona and *Leucosphere* which is given in his report; and to have devoted some seconds to checking the accuracy of his assistant, by examining the position of the cross-wires of his finder upon the corona. In addition to all these observations, he twice altered the breadth of his slit during totality, and gave signals for the commencement and end of the total phase, of which it will be noticed that he gives the time to two decimal places of a second. Lieutenant BROWN's observations were made through passing cloud, but he seems to have lost the bright line of the corona while he observed the continuous spectrum. On the other hand, HERSCHEL and ABBAY, whose observations were also made through cloud, observed the bright line, while they lost the faint continuous spectrum.

* One would gather from RIHA's remark that his slit was not too widely open at the time to have shown the more conspicuous Fraunhofer lines. He was at a loss to account for there being no dark lines, and mentions that he examined his slit to see that all was in order.

† POGSON, however, adds that the spectrum was "certainly free" from dark lines,—a remark which implies that the spectrum was distinctly seen.

that the spectrum became "almost black, but with the colours still traceable." These various estimates of brightness may no doubt easily be reconciled, when we consider that the brightness of the corona differs considerably from eclipse to eclipse, and that the brightness of the spectrum as seen with analyzing spectroscopes would differ greatly as the slit was placed upon various parts of the corona. The fact that so many observers speak with certainty as to the non-existence of dark lines, shows that the continuous spectra observed by them must have been something more than a just perceptible trace of nebulous light in the field of their spectroscopes.

Colours observed in the continuous spectrum

Some clue to the brightness of the continuous spectrum may possibly be obtained from the remarks made by observers as to the colour * of the background on which the bright lines of the coronal spectrum have been seen. POGSON, RAYET, and RESPIGHI describe the continuous spectrum as scarcely coloured; while HAMMOND and FYERS, using integrating spectroscopes, and DENZA, LORENZONI, JANSSEN (?), and STONE,† using analyzing spectroscopes, speak of definite colours.

STONE, it will be seen, mentions that the spectrum of the inner corona appeared to him to be rich in red light; and HAMMOND (the weight of whose observation is, however, considerably diminished by the fact that he did not observe the green coronal line) concurs with STONE in asserting that the continuous spectrum of the corona is deficient in light of short wave-lengths. DENZA, however, whose observation was made through cloud, was of a contrary opinion.

If the continuous spectrum of the corona is principally due to light dispersed by particles whose diameters are small compared with the wave-length of light (as the considerations referred to in the introduction to the Polarization chapter would lead us to conclude), we should expect to find the continuous spectrum of the corona rich in blue rays. For it may be

* In the spectrum of very faint light the colours are not distinguishable. Making use of a spectroscope with prisms of dense flint glass, and observing in a darkened room with faint sunlight, the blue is first lost to my eye, then the red, and lastly the green colour about the region of E., is lost. The remaining trace of light, which is quite sufficient to show the position of the wires of the micrometer, appears to me as a faint grey.

† We have not referred to the observations of FUSINIERI, MAGRINI, DUNKIN, and BARREDA, as their observations were made with prisms without slits, and it is not certain that the spectra they describe were derived from the corona.

shown * that when light is scattered by particles which are small compared with any of the wave-lengths of the visible part of the spectrum, the ratio of the amplitudes of the vibrations of the scattered and incident light varies inversely as the square of the wave-length, and the intensity of the lights is consequently as the inverse fourth power of the wave-length. It should, however, be remembered that the richness of the violet end of the spectrum is by no means a marked feature of the spectrum of the light derived from the blue sky. It is not until the intensities of the light of various parts of the spectrum of sky light and direct sun light are compared photometrically, that the rapid increase of intensity at the violet end of the sky-light spectrum becomes apparent.

Owing to the strange conditions of illumination during totality, and the sense of contrast produced by the deep colour of the sky on the one hand and the prominences on the other, the eye-estimates of the colour of the corona cannot be greatly relied upon, and it would therefore be well that during future eclipses greater attention should be directed to the distribution and intensity of the light at various parts of the continuous spectrum of the corona.† LORENZONI is, as far as we are aware, the only observer who has described a broad band of increased brightness in the green.

* See a paper "On the Light of the Sky, its Polarization and Colour," by the Hon. J. W. STRUTT (now *Lord Rayleigh*), in the *Phil. Mag.* for Feb. 1871, pp. 107—120, and March 1871, pp. 274—279.

† Such an examination would, no doubt, throw important light on the constitution of the corona. An excess of red light in the continuous spectrum of the corona might, we would suggest, be accounted for by assuming that the small particles in the corona which disperse the sun's light are incandescent at a red heat. Other considerations would seem to indicate that such an assumption is by no means improbable. The observations cited in the introduction to the chapter on *Polariscopic Observations* (p. 260), tend to show that the polarization of the corona increases in intensity on proceeding outwards from the moon's limb, until at a certain distance the maximum intensity of polarization is attained. As if in the lower corona the polarization of the dispersed sunlight were masked by emitted light, while in the higher regions of the corona the dispersed sunlight altogether overpowers the weaker emitted light.

It will be seen that STONE's observation, as to the richness in red rays, only refers to the continuous spectrum derived from the inner corona, and that during a somewhat rapid observation he was unable to detect dark lines in the spectrum of the inner corona, while he saw them in the spectrum of the outer corona. This again would look as if there were emitted light masking the solar light in the regions of the lower corona.

The particles which disperse the polarized light in the lower parts of the corona are, as we know, distributed over an area which is also occupied by gas in a condition sufficiently hot to give a bright-line spectrum. We have no clue at present to the temperature of the gas; but if

List of Observers who refer to Colours seen in the Continuous Spectrum of the Light of the Corona.

1868.	**Pogson.**	A faint light scarcely coloured.
	Rayet.	Sur un fond uniforme presque noir, ou plutôt d'un violacé très-obscur; aucune trace de spectre coloré donné par la couronne.
1870.	**Hammond.**	A spectrum in which red and green were present, but the blue and violet absent.
	Denza.	Il fondo, su cui si proiettavano le due righe, era di un verde scuro, il quale diveniva più chiaro e tendente al giallo nell' avvicinarsi alla seconda riga. Nel rimante campo dello spettroscopio, e massime dal lato dei colori meno rifrangibili, mi sembrò intravedere la continuazione dello spettro continuo, ma debolissimo.
	Lorenzoni.	Una banda di luce verdognola sfumata da una parte e dall' altra.
1871.	**Janssen.**	La raie obscure D, se perçoit, ainsi que quelque lignes obscures dans le vert.
	Respighi.	The coloured zones (corresponding to the corona) shone out upon a faintly illuminated ground without any marked trace of colour.
	Fyers.	The spectrum became almost black, but with the colours still traceable.
1874.	**Stone.**	A spectrum which appeared to me continuous, but rich in red light.

Evidence as to the presence of absorption lines in the continuous spectrum of the corona.

RIHA, TENNANT, and POGSON in 1868, HARKNESS, PICKERING and YOUNG in 1869, and BROWN, MACLEAR, PYE, WINLOCK, YOUNG and BURTON in 1870, all mention that they looked for dark lines in the spectrum of the corona, but were unable to detect any trace of them. JANSSEN, however, in 1871, speaks with confidence of having observed the dark line D, as well as some very faint dark lines in the green: he mentions that they were visible at a medium height in the corona, and explains that he means from 3′ to 6′ above the limb—implying that he had failed to see the dark lines at higher or lower altitudes. STONE in 1874 also speaks with confidence of dark lines in the spectrum of the outer corona; but from a somewhat hurried examination of the spectrum of the inner corona, he was inclined to think that it was continuous without dark lines.

the particles emit light which can be proved to be rich in red rays, we may assume that their temperature is not very great—for example, is not equal to, or comparable with, the temperature of melted iron.

In connection with this question, see the observation of MAGRINI, referred to on pp. 244 and 245, which tends to show that the heat derived from the corona and solar appendages is very great compared with that derived from the full moon: but too much reliance must not be placed on MAGRINI's observation, as it is very imperfectly described, and much would depend upon the exposure of the thermopile previous to totality, as well as upon other minor matters which are not referred to.

In weighing the negative evidence referred to above, it should be remembered that the observations of TENNANT, POGSON, HARKNESS, and YOUNG, 1869, all relate to the spectrum of the corona near * to the sun's limb. RIHA, TENNANT, POGSON and BROWN failed to detect the bright lines of the corona, and consequently their negative evidence with regard to the dark lines cannot be considered as very important. PICKERING and PYE were using integrating spectroscopes; and if it should be shown that the lower parts of the corona give a continuous spectrum without dark lines, the absence of dark lines in the integration spectrum may be readily accounted for by assuming that the brighter spectrum of the lower corona obliterates the lines in the faint spectrum of the upper parts of the corona. The observations of MACLEAR, WINLOCK, YOUNG and BURTON, in 1870, were all made through cloud; which would no doubt also have the effect of mixing the light from various parts of the corona, and thus superposing the spectrum of the lower corona upon the faint spectrum of the upper portions of the corona.

Observations as to the Presence of Dark Lines in the Continuous Spectrum of the Corona.

1868.	Riha.	Sobald der letzte Lichtstrahl der Sonne verschwand, verschwanden auch momentan alle Fraunhofer'schen Linien, und es ging das Spektrum mit einem Schlage in ein continuirliches über.
	Tennant.	What I saw was undoubtedly a continuous spectrum, and I saw no lines. There may have been dark lines, of course; but with so faint a spectrum, and the jaws of the slit so wide apart, they might escape notice.
	Pogson.	A faint light was seen, certainly free from either dark or bright lines.
1869.	Harkness.	Remembering that the observers in India, in August 1868, had said that the corona gives a continuous spectrum *with absorption lines*, I looked very carefully for them, but to my great surprise I could see none, and I am perfectly satisfied that none were visible in my instrument. [The slit was about 5′ from the sun's limb.]
	Pickering.	Continuous spectrum, without dark lines.
	Young.	A faint continuous spectrum, without any trace of dark lines in it.

* TENNANT says that he "set the cross-wires immediately outside the upper limb;" POGSON that he directed the finder of his spectroscope telescope to a part of the corona on the sun's southern limb, as clear of any visible prominences as possible; and HARKNESS, judging from the position of C_3 in his diagram, cannot have had his slit at the time of the observation at a distance of more than 4′ or 5′ from the sun's limb. YOUNG, in 1869, appears to have confined his observations chiefly to the prominence region.

1870.	**Brown.**	A continuous spectrum, free from any lines, bright or dark.
	Maclear.	I observed no dark absorption bands.
	Pye.	Continuous spectrum seen when the slit was opened; no dark lines observed.
	Winlock.	During my examination of the corona I looked carefully for dark lines, but saw none. [The slit was placed upon various parts of the corona near to the sun's limb, and as far as 25′ from the limb. The observation was made through clouds.]
	Young.	I saw no trace of dark lines, although I looked for them carefully. [The slit was placed upon various parts of the corona near the sun's limb, and as far as 16′ from the limb. The observation was made through drifting cloud.]
	Burton.	No dark lines were seen in the corona spectrum. [The observation was made through drifting cloud.]
1871.	**Janssen.**	Dans les hauteurs moyennes de la couronne, de 3 à 6 minutes d'arc, la raie obscure D se perçoit, ainsi que quelques lignes obscures dans le vert, mais celles-ci sont à la limite de visibilité.
1874.	**Stone.**	The spectrum of the inner corona appeared to be continuous without dark lines, but the examination was too imperfect to allow of a confident opinion being expressed. In the spectrum of the outer corona dark lines were observed with certainty, although they were seen with great difficulty.

Distance from the Sun's Limb to which the Continuous Spectrum of the Corona has been traced.

Height to which the continuous spectrum has been traced.

YOUNG, whose observation in 1870 was made through drifting cloud, mentions that a faint continuous spectrum, much brighter near the sun, always formed a background for the bright lines; he traced 1474 to a distance of 16′ from the limb, and we may therefore no doubt assume that the continuous spectrum was traceable to a distance of more than a solar radius from the limb. WINLOCK, whose observation was also made through cloud, saw bright lines upon a continuous spectrum, which he describes as "not very faint": at the time of making this observation it appears that his slit was at a height of 12′ above the limb. He then traced the bright lines to a height of 25′; but his account does not expressly state whether the continuous spectrum was visible at a similar altitude. BROWN speaks of having observed a continuous spectrum without bright lines at a height of 25′ above the limb; but his observation, which was made through clouds, must have been of a very hurried character. He says that he saw the continuous spectrum to "about the top of the corona."

In 1871 LOCKYER and JANSSEN both describe the continuous spectrum as being brighter than they expected, but neither of them traced it to any considerable distance from the limb. HERSCHEL found a faint continuous spectrum at a height of 16′ above the west limb. When his slit was placed across the edge of the great southern rift he noticed that the part of the field corresponding to the rift "was far from dark": at the time of this observation the southern end of the slit, which was 18′ long, must have been about 20′ from the nearest part of the sun's limb.

In 1874, STONE, in observing the spectrum of the outer corona, found the field of his spectroscope sufficiently illuminated to admit of the presence of dark absorption lines being made out with certainty. He does not mention the height above the sun's limb to which his observation of the dark lines referred, nor does he appear to have determined the distance to which the continuous spectrum could be traced; but if we may judge from the analogy of HERSCHEL's observation of 1871,—that the continuous spectrum is traceable to a greater distance from the sun than the bright-line spectrum,—the light of the continuous spectrum must have been visible with the clear sky of Klipfontein to a distance of more than three-quarters of a degree from the sun's western limb.

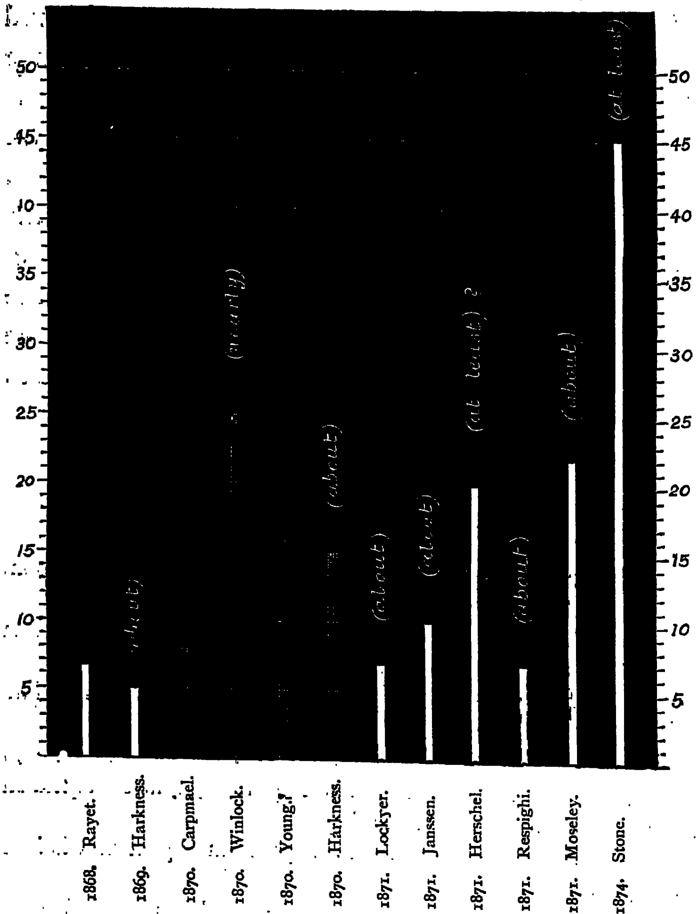
List of Observations referring to the Height of the Continuous Spectrum.

1869.	Harkness.	Continuous spectrum about as bright as that given by the full moon. [Slit 5′ at most from the limb.]
1870.	Brown.	Continuous spectrum free from lines. [Slit at places on the corona between 4½′ and 25′ from the limb.]
	Winlock.	Continuous spectrum not very faint. [Slit 12′ from the limb at the time of this observation.]
	Young.	A faint continuous spectrum, much brighter near the sun, always formed a background for the bright lines. [The 1474 line was traced to a distance of 16′ from the E. limb.]
1871.	Lockyer.	Astonished at vividness of the continuous spectrum. [Slit at a height of about 7′.]
	Janssen.	Le spectre se montre beaucoup plus vif que je ne m'y attendais à cette distance. [Slit at two-thirds of a radius from the limb.]
	Herschel.	I still saw coronal light here, though it was faint. [Slit at about 16′ from the W. limb.]
1874.	Stone.	The spectrum of the outer corona was sufficiently bright to allow of absorption lines being seen, although with great difficulty. [Position of slit at the time of the observation not given.]

Distance from the Sun's Limb to which the Bright Line 1474 *has been traced.*

Height to which the bright line 1474 has been traced.

The accompanying woodcut will assist the reader in forming an estimate of the evidence brought together in the present chapter with regard to the height to which the bright line 1474 has been traced, as extending above the sun's limb. The thick white lines correspond to observations which have been made with a clear sky: the shaded lines to those which have been made through cloud, or with a hazy sky. That observations of the second class must be received with caution, is proved by the fact that MACLEAR, observing with a cloudy sky, in 1870, saw a bright-line spectrum when his slit was at the centre of the dark moon. YOUNG in 1870, observing through what he describes as "haze and flocculi of cloud," saw the C and D_3 lines extending on to the disc of the moon. But in the case of observations made with a clear sky, the diffusion of light is not sufficient, it would seem, materially to affect the height to which bright lines can be traced. This is proved by the observations of JANSSEN,* HERSCHEL, and MOSELEY—the latter two



Heights to which the bright line 1474 has been traced. The shaded lines refer to observations made through cloud.

* JANSSEN placed his slit radial to the limb, so as to lay partly on the moon's disc. He describes the spectrum corresponding to the place of the moon's disc as "*excessivement pâle.*"

of whom were unable to detect any trace of spectrum when their slits were placed at the centre of the dark moon. JANSSEN, whose observation was made from a station where the sun was not very far removed from the mist and haze of the horizon,* saw an excessively faint spectrum from the edge of the disc of the dark moon. The observations of RAYET in 1868, HARKNESS in 1869, and STONE in 1874, were made with a clear sky, and with the sun much higher above the horizon than as seen from the Indian and Ceylon stations during the eclipse of 1871.

With regard to the distance to which the 1474 line can be traced in various directions from the sun's limb, further observations are required. YOUNG, in 1870, found the area within which the 1474 line was visible extending rather further on the east and west than to the north and south. But RESPIGHI, in 1871, speaks of the green zone as sensibly circular. WINLOCK does not mention the direction in which he traced the 1474 line to the height of 25'.† But MOSELEY and STONE's observations were both made in the equatorial regions of the corona; MOSELEY in 1871 traced the green line 22' towards the east, while HERSCHEL by his third observation appears to have traced it nearly 20' to the south. The enormous extension of more than $\frac{3}{4}^{\circ}$, observed by STONE in 1874, was from the western limb.

The slit of Herschel's spectroscope was placed by TENNANT, who was directing his instrument, at the centre of the dark moon. After a careful inspection, HERSCHEL reported that nothing was visible. MOSELEY placed the slit of his spectroscope on the dark moon's centre, but "got no spectrum whatever."

* Janssen, however, describes the sky as being perfectly clear at the time of his observation. On p. 18 of his "Rapport à l'Académie" he says: "Vers $5^h\ 30^m$, et quand l'aube était bien accusée, le vent s'éleva comme à l'ordinaire, et un rideau noir menaçant s'avança sur nous. Nous voyions très-bien le Dodabetta [Captain Herschel's station] dans les nuages. Mais . . . . les nuages s'arrêtèrent, et au moment du premier contact le soleil était tout à fait audessus." At p. 28 he says: "Si nos émules étrangers n'ont pas obtenu un résultat aussi décisif que celui de la mission française, je crois qu'il faut l'attribuer à la pureté tout exceptionnelle du ciel dans la station que j'avais choisie avec tant de soins, et aussi à l'ensemble des dispositions optiques." At Dodabetta, where no spectrum was detected at the centre of the dark moon, the mist over the sun's place was sufficient to cause Mr. Hennessey to alter the exposures of the photographs which had previously been determined upon on the supposition that the sky would be clear.

† LANGLEY, in his summary of the Spanish observations, published shortly after the eclipse in *Nature*, describes WINLOCK as having followed 1474 all round the sun to at least 20' from the disc. But it is evident, from WINLOCK's description of his own observation, that he had great difficulty in observing the corona on account of the clouds; and the presence of the line near D at so great an altitude above the sun's limb would lead us to accept his observation with great caution.

List of Observations referring to the Height to which the Bright Line 1474 *has been traced.*

1868. **Rayet.** A green line which Rayet called E was seen extending to about double the height of the other prominence lines. It would seem, from Rayet's description, that the other prominence lines corresponded in height with the prominences. (The height of the green line would therefore be nearly 7′.)

1869. **Harkness.** A line whose position Harkness gives as 1497 K was seen when the slit of his spectroscope was at a part of the corona marked C_3 in Eastman's diagram. (If we leave out of account the length of the slit, this would correspond to a height of not quite 5′.)

Young. 1474 was seen extending clear across the spectrum; and on moving the slit away from the protuberance it persisted, while D_3, visible at the edge of the field, disappeared. (Height to which the 1474 line could be traced not given.)

1870. **Carpmael.** Observation made through passing clouds. A green line, whose position is given as 1359 K, was seen extending entirely across the field of the spectroscope. The slit, whose length corresponded to about 30′ of arc, was, at the time of the observation, tangential to the east limb, and placed so as "just to be clear of the solar flames." (Taking the height of the centre of the slit above the limb as 3′, the extremities of the slit would be at a height of more than 8′.)

Maclear. Observation made through cloud. Bright band near *b* seen when the slit was 8′ from the limb. But as the same spectrum was observed when the slit was at the centre of the moon, we have not included Maclear's observation in the diagram illustrating the observations of the height of the green line.

Winlock. Observation made through cloud. 1474 traced to a height of nearly 25′ from the limb.

Young. Observation made through "haze and flocculi of cloud." 1474 observed growing fainter as the distance from the sun increased. It was traced to a distance of 16′ from the east limb, 13′ from the west limb, 12′ from the north limb, and 10′ from the south limb.

Harkness. Observation made through passing clouds. 1474 traced to a distance of certainly not less than from ten to fifteen minutes from the sun.

1871. **Lockyer.** 1474 observed extending slightly beyond the hydrogen spectrum. It was seen to thicken downwards like F. (At the time of this observation the slit was estimated to be at a height of about 7′.)

Janssen. 1474 observed when the slit was placed at a height of about two-thirds of a radius from the limb. The spectrum was observed to increase in intensity as the slit was brought up to the limb.

Herschel. Slit across the edge of the great southern rift at "about 10′ from the limb." This estimate of distance seems to refer to the centre of the slit: if so, the southern end of the slit, which was 18′ long, must

have been nearly 20′ from the limb. The 1474 line was seen extending all across the field.

Respighi. Green zone well defined at the summit, which was less bright than the base. Its form was sensibly circular, and its height about 6′ or 7′. The green zone was brighter and more uniform than the zones corresponding to hydrogen.

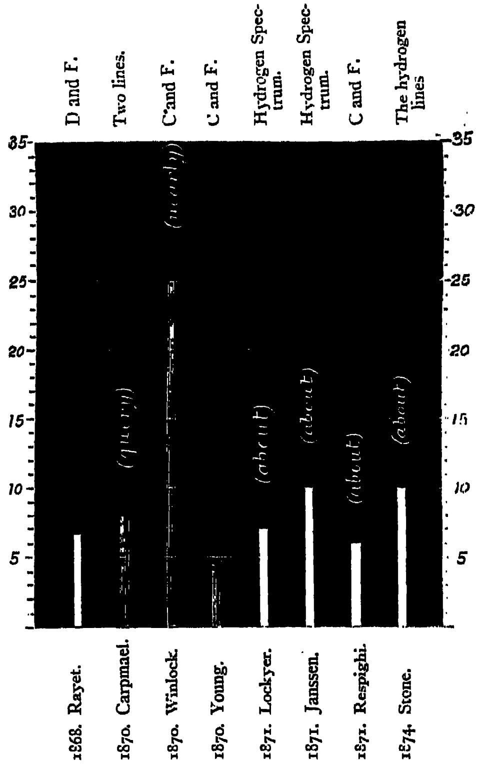
Moseley. The line 1474 was traced to a distance which was estimated to be 22′ from the sun's eastern limb.

1874. **Stone.** As the slit was carried away from the sun's western limb, the bright line 1474 gradually became fainter, until it was lost sight of from extreme faintness. When the line was last seen, the slit must have been more than a degree from the sun's centre.

Distance from the Sun's Limb to which Lines of the Hydrogen Spectrum have been traced.

Height to which the hydrogen spectrum has been traced.

It will be seen by an inspection of the accompanying woodcut that Winlock is the only observer who has traced the hydrogen spectrum to a greater height than 10′ above the sun's limb. But his observations were made with a cloudy sky; and the presence of "the line near D," which has only been seen by other observers in the immediate neighbourhood of the prominences*—at an altitude of 25′ above the limb—seems to render it probable that the spectrum he observed was really due to the light of the prominences dispersed by clouds.



Heights to which lines of the hydrogen spectrum have been traced. The shaded lines refer to observations made through cloud.

Most of the observers—viz., Rayet (?) Carpmael (?) Winlock, Young, and Respighi—appear only to have observed the C and F lines. Janssen says that he immediately recognized the spectrum of hydrogen, but does not mention which of the lines he saw. Lockyer, observing

* See remarks on the absence of D_3 from the spectrum of the corona, on pp. 347 and 348.

Height to which the hydrogen spectrum has been traced.

with an analyzing spectroscope, says that he saw a vivid hydrogen spectrum, and that he was astonished at the "vividness of the C line," but he does not mention which of the other hydrogen lines were visible. Observing with a prism without a slit, he recorded rings corresponding to C, F and G,—by which he probably means C, F, and H_γ (the hydrogen line a little below G). He mentions that all these rings were brighter than the ring corresponding to 1474, but he does not appear to have seen any ring corresponding to H_δ. On the other hand, RESPIGHI found the hydrogen rings less bright than the 1474 ring. It would seem that RESPIGHI only saw two rings belonging to the spectrum of hydrogen —a red and a blue one—which he suggests probably corresponded with the C and the F lines. He adds that if the corona contained rays of any other kind, their intensity must have been so feeble that they were merged in the general illumination of the field. The relative brightness of the four hydrogen lines in the chromosphere, as given by YOUNG, is H_α or C, 100; H_β or F, 80; H_γ, 65; H_δ or *h*, 50. But it does not by any means follow that the relative brightness of the lines would be the same with the different conditions of heat and pressure existing at various altitudes in the corona.

RESPIGHI mentions that the red image was sensibly circular, and was distinct and well defined, though its light was *less uniform* than that of the green image; but it does not appear whether by "less uniform" he intends to imply that the rifts and coronal details were visible in the red image while they were invisible in the green image, or merely that the red image was not so "well defined at the summit" as he describes the green image to have been. It will be noticed, however, that with the exception of this observation and that of LOCKYER, who saw the rings corresponding to the hydrogen spectrum extending only to a height of 2′ above the limb, all the other observations of the spectrum of hydrogen refer to parts of the corona near to the equatorial regions of the sun—and that there are no observations which can be relied upon as proving that the spectrum of hydrogen has been observed from the area of rifts.

List of Observations referring to the Height to which Lines of the Hydrogen Spectrum have been traced.

1868. **Rayet.** The line F, and a line which Rayet speaks of as D (but which we may probably assume was C, for the C line of the hydrogen spectrum is much brighter than the F line), were traced to double the height of the other prominence lines, or to nearly 7′ above the limb.

1870. **Carpmael.** Observation made through an opening in passing cloud. When the green coronal line was near the centre of the field of view, two other lines were seen towards the extremities of the field, "not equally distant from the middle line." Carpmael states that the bright coronal line (he uses the word in the singular) extended entirely across the field of view; but he does not state that the other lines were shorter than the central line. The centre of the slit seems to have been about 3′ from the limb, and the extremities of the slit must have been more than 8′ from the limb.

Winlock. Observation made through cloud. C and F traced to nearly 25′ from the limb. (The diffusion of the light of the prominences by the clouds seems to have been very considerable, as the line near D was traced to the same altitude.)

Young. Observation made through cloud. C traced to a distance of 4′ or 5′ outside the sun. F traced not quite so far. (D_3 traced to the same distance as C.)

1871. **Lockyer.** A vivid hydrogen spectrum extending not quite as far from the limb as the 1474 line. (Lockyer estimates that the height of his slit at the time of this observation was about 7′.)

Janssen. Spectrum of hydrogen seen when the slit was about two-thirds of a solar radius from the sun's limb.

Respighi. A red zone seen, probably corresponding with the line C, and a blue zone "perhaps coinciding with F." The red zone was very distinct and well defined, while the blue zone was faint and indistinct. The height of the red zone was about 6′ or 7′.

1874. **Stone.** On sweeping across the inner corona the hydrogen lines were seen extending all across the slit. (Judging from the diagram accompanying Stone's report, the height of the inner corona was at least 7′.)

Distance from the Sun's Limb at which the Faint Lines less refrangible than 1474 have been observed.

None of the observers who have seen the faint lines less refrangible than 1474 mention the height to which these lines could be traced above the sun's limb. Young, in 1869, said that he had an impression that

Height to which the faint lines, less refrangible than 1474, can be traced.

the two faint lines whose position he gives as 1250±20 and 1350±20* extended all across the spectrum, and that on moving his slit away from a prominence they persisted. He does not, however, mention the distance from the sun's limb to which his slit was carried; but the length of his slit, which seems to have been placed radially to the sun's limb, was not quite 2′. DENZA does not give the place of his slit upon the corona at the time that he observed the line whose position he gives as 1246; but from his description one would judge that it remained visible as the slit was shifted in position upon the corona, for he satisfied himself that the line was not due to the prominences by observing that, as his slit was moved, other very brilliant lines came into view, and again disappeared when the slit was shifted, leaving the green coronal line and 1246 still visible. HARKNESS also saw "two green lines," fainter than 1474, and "of a less degree of refrangibility"—which, he says, he was "pretty confident belonged to the corona." The lines appear only to have been seen for an instant through passing cloud; but neither he nor TUPMAN, who was directing his spectroscope, give any clue by which the height of the slit at the time of this observation can be determined. STONE, observing in 1874, says that on sweeping his slit across the inner corona—the height of which, judging from his diagram, cannot be estimated at much less than 10′—he saw "two or more" lines much fainter than 1474, and of less refrangibility. He spent, however, but little time in examining the spectrum of the inner corona, and he does not state whether he was able to trace these lines to the extreme limits of the inner corona, or even as high as the hydrogen spectrum.

But the negative evidence with regard to the presence of the faint lines in the spectrum of the corona must not be passed over in silence. YOUNG and the other observers of 1870, who did not succeed in observing the faint lines, made their observations through cloud, which may have obliterated the fainter parts of the spectrum. But the observers in India

* It is worth remarking, that the only chromosphere lines between 1474 and D_3 to which YOUNG has given high frequency numbers lie near to these limits. In YOUNG's catalogue of chromosphere lines observed at Sherman, published in the *American Journal of Science and Arts* for November 1872, he gives the line 1274·2 K. with a frequency number 50, and the iron line 1281·3 K. with a frequency number 40. The only other line between 1474 and D_3 to which he attaches a frequency number higher than 15 is 1372·1 K.; for this he gives the frequency number 25.

and Ceylon in 1871 made their observations with a clear sky, though the sun was not very far removed from the mist and haze of the horizon. JANSSEN, however, made use of an instrument of large aperture and short focus, with collimator and telescope adapted to take in the whole pencil; but though he describes the instrument as especially fitted for observing the spectrum of faint objects,* it is possible that its great angular aperture may have been more than counterbalanced by absorption and reflexion from the surfaces of the two compound prisms which he made use of. He describes each of them as being composed of five prisms of very pure glass, united by Canada balsam; but he does not mention the size of the prisms or the thickness of glass traversed by the pencil. No doubt, even with the whitest flint and crown glass, the loss by absorption and reflexion from the surfaces of the prisms would greatly reduce the intensity of the transmitted beam.

Does the Matter corresponding to the 1474 *Line form a Continuous Envelope uniformly incandescent about the Sun?*

HERSCHEL in 1871, when the slit of his spectroscope was placed across the edge of the great southern rift, so as partly to lie upon the corona and partly to extend into the area of the rift, observed that the 1474 line extended into the part of the field of his spectroscope which corresponded to the area of the rift.

The bright line 1474 traced into a rift. Herschel and Tennant's observation.

It will be seen by reference to Plates 7 and 8 at the end of the volume that the eastern edge of the great southern rift presented a most marked transition from darkness to intense brightness. TENNANT says that he placed the slit about 10′ from the limb; and assuming that his estimate refers to the cross-wires indicating the centre of the slit in the finding telescope, the northern half of the slit would have been upon one of the brightest parts of the corona, while the southern half would have stretched out into a part of the rift which appears almost black in the photographs; but, as Capt. HERSCHEL has informed us, he was unable to detect any sudden change in the intensity of the pale green line 1474, which stretched

* M. JANSSEN says of his instrument, "Ce spectroscope était si lumineux qu'il donnait le spectre des corps les moins éclairés de l'intérieur d'une chambre,"—and after describing part of his observation he adds, "résultat qui tient évidemment au grand pouvoir lumineux de l'instrument, et à l'ensemble des dispositions adoptées."

all across the field of his spectroscope. This is the more remarkable as the southern rift, and especially the eastern edge of it, was noticed by the most casual observers of the eclipse of 1871.

The observation was made with a clear sky, and, it will be seen, tends to prove that the incandescent gaseous matter which gives the bright line 1474 was distributed throughout the area of the rift. This conclusion is rendered still more probable by the curving structure of many of the bright details of the corona, which would seem to indicate that the jets or streams of fine particles which give the bright partly polarized light of the corona are affected by currents which carry them out of their original course. The contrary flecture of the eastern edge of the great southern rift under consideration is an instance of the stream-like action we refer to.

Respighi's observation.

The language of RESPIGHI with regard to the even distribution of the light of the green zone * seems to indicate that the matter corresponding to 1474 forms a continuous envelope about the sun. In the French account of his observations he definitely states that the green ring was approximately circular, and that he traced it all round the sun. The parts of the images which overlapped would about correspond to the places of the great northern and southern rifts; but he seems to have been able to trace the green ring, by reason of its marked superiority in brightness and the definiteness of its outline, through the confused light of the superposed images; and in summing up his observations he distinctly asserts that none of the structure, which was seen by naked-eye observers of the corona, was to be recognised in this gaseous stratum.

But RESPIGHI's observations with regard to the red and blue zones are by no means so definite. He describes them as less uniform than the green zone, and there is nothing to show that the hydrogen spectrum was visible in the area corresponding to the great rifts. Judging from the analogy offered by what is ordinarily called the chromosphere (*i.e.*, the parts of the solar envelope where the gases are so intensely incandescent

* RESPIGHI says: "The green zone surrounding the disc of the moon was the brightest and most uniform, and the best defined; the red zone was also very distinct and well defined, while the blue zone was faint and indistinct. The green zone was well defined at the summit, though less bright than at the base; its form was sensibly circular, and its height about 6′ or 7′. The red zone exhibited the same form and approximately the same height as the green, but its light was weaker and less uniform."

that the bright lines of their spectra can be seen superposed on the spectrum of our atmosphere as illuminated by the sun), the light of the hydrogen images would not be evenly distributed, but the parts corresponding to ascending currents, or to masses of gas which had but recently occupied a lower level, would appear more intensely incandescent. It is possible, however, that in the regions of the upper chromosphere* the incandescence may be more uniformly distributed, and the differences of brightness due to differences of temperature of ascending and descending masses of gas may be insignificant compared with the brightness due to the temperature of the region. On another occasion the observation of Respighi should be repeated, and especial attention should be paid to the distribution of the light of the hydrogen images, and to the question whether there is any connection between the structure of the corona visible to the naked eye or in the photographs and the areas of greatest brightness in the C and F images.

Gordon, who directed the instrument of Carpmael in 1870, placed the slit of the spectroscope tangentially to the east limb of the sun, so that the centre of the slit was at a height of about 3′ above the limb. Carpmael says that "the bright corona line extended entirely across the field of view, but was fainter towards the extremities." The upper part of his field, which would correspond to the southern end of the slit, was occupied by a comparison spectrum. The length of the slit was equivalent to about thirty minutes of arc; and it will be seen, by comparing the woodcut illustrating the place of Carpmael's slit with Plate 6, that the slit extended across a part of the corona where there was no very sudden transition from light to darkness. The southern end of the slit would have been upon the lower part of the south-eastern rift;† but this part of the slit may have been occupied by the comparison spectrum, and if not, the clouds through which Carpmael's observation was made may possibly have superposed the light from different parts of the corona, so that his observation cannot be relied on as evidence tending in either direction.

Other observations referring to the presence of the 1474 line in the spectrum of rifts.

* If this term is not approved of, and the term lower corona is considered too indefinite, we might with advantage make use of the expression "region of gaseous incandescence," or, more shortly, "1474 region," "hydrogen region," meaning the regions in which 1474 matter or hydrogen is sufficiently hot to give out bright lines.

† Which extends from position angle about 100° to about 130°.

BROWN, in 1870, says that he directed his cross-wires to be placed at the centre of the great southern rift, and that "the spectrum gave no lines." But as he saw no lines in the spectrum of any other part of the corona, his evidence may be neglected. So also may the evidence of MACLEAR, who swept his slit across the area of the great northern and southern rifts of the corona of 1871. It seems that he also placed his slit upon bright parts of the corona, but saw no spectrum.

The 1474 line not seen in the spectrum of a prominence, though visible in the corona.

JANSSEN, in 1871, placed his slit, which was 10′ long, radial to the moon's limb, so as to cut a prominence and extend outward upon the corona. The hydrogen lines of the prominence appeared prolonged upwards into the part of the field corresponding to the corona, but the 1474 line, which was bright in the corona, appeared interrupted in the spectrum of the prominence. He draws especial attention to this observation; but it will be remembered that the 1474 line is not always equally bright in the spectra of prominences, and that sometimes, when their spectrum is observed under ordinary daylight conditions, the 1474 line is altogether invisible. It will be seen also from the next section that in the spectrum of the lower corona or upper chromosphere the 1474 line appears to be the brightest line in the spectrum, while in the spectrum of the prominences it ranks only as the fifth or sixth line in average brightness.* It is possible, therefore, that JANSSEN may have been struck by the sudden decrease in relative brightness of the 1474 line in passing from the spectrum of the corona to the prominence spectrum, and in his haste have supposed that it was altogether absent in the latter. A moment's reflection will show that, since the prominences are seen through the corona, the spectrum of the corona will always be seen superposed on that of the prominences. In opposition to the observation of JANSSEN it will be noticed that RAYET, in 1868, saw the green line of the corona much brighter in the part of the spectrum corresponding to the prominence than

* The numbers corresponding to the average brightness of the most conspicuous prominence lines, as given by YOUNG in his catalogue of chromosphere lines, are—C, 100, D_3, 90, 1474, 50, F, 80, $H\gamma$, 65, and *h*, 50. In referring to the relative brightness of the C and the 1474 lines, in his paper "On the Solar Corona," published in *The American Journal of Science and Arts*, vol. i., May 1871, p. 5, Prof. YOUNG estimates the relative brightness of the C and 1474 lines as about equivalent to the relative brightness of a star of the first and one of the fifth or sixth magnitude; in other words, he estimates C as between twenty-five and one hundred times as bright as 1474.

in that corresponding to the corona,* and YOUNG, in 1869, saw the 1474 line in a prominence, and traced it outwards some distance into the corona. In his note he speaks of it as retaining its brilliance at some distance from the prominences.

Brightness of the Lines seen in the Spectrum of the Corona.

From the fact that so many observers have been able to trace the 1474 line to a considerable distance from the sun's limb, while they have not seen any trace of the lines of the hydrogen spectrum, it will be gathered that the 1474 line must, as observed with analyzing spectroscopes, appear considerably brighter than the hydrogen lines in the spectrum of the corona. **Relative brightness of the lines seen in the spectrum of the corona with analyzing spectroscopes.**

RAYET's sketch of the spectrum of the great prominence seen in 1868 does not indicate any difference in the brightness of the three lines (traits lumineux) which he observed extending upward into the part of the field corresponding to the corona; but CARPMAEL, in 1870, speaks of the green line as "the bright corona line," and RESPIGHI, in 1871, observing without a slit, says that the green zone was brighter than the red and blue zones, while LOCKYER, who was also observing without a slit, but with five prisms of 45°, which would greatly decrease the intensity of the light,† describes the 1474 ring as less bright even than the faintest of the hydrogen rings; but it will be noticed that the rings observed by LOCKYER were "certainly not more than 2′ high," while those observed by RESPIGHI extended to a height of 6′ or 7′. LOCKYER mentions that the rings showed "projections where the prominences were," as if the images he observed corresponded to incandescent matter which had but recently been erupted from lower and hotter regions and was not yet uniformly diffused; while RESPIGHI, on the other hand, mentions that the green zone (which is the one he most minutely describes) appeared perfectly uniform and had a well-defined approximately circular upper limit. It seems, therefore, probable that

* This is clearly indicated by his language, as well as by the thickness of the prominence lines in his sketch. He says: "Les lignes *très-vives*, D, E, et F, se continuaient au delà de la longueur moyenne par un trait lumineux *très-faible*."

† In observing with his other instrument, with a slit and but one prism of 60°, LOCKYER seems to have traced the hydrogen spectrum and the 1474 line to a height of 7′. In describing this observation he does not definitely state that the 1474 line was less bright than the C line; but his language would seem to imply that it was so.

LOCKYER'S observation refers to the relative brightness of the monochromatic images of the comparatively hot incandescent matter erupted into the lower parts of the corona, while RESPIGHI'S observation refers to the relative brightness of the images of a higher region. If this interpretation of the observations is correct, it illustrates the difference in the relative brightness of the 1474 line and the hydrogen lines as seen in the spectrum of the lower corona, and in the spectrum of the chromosphere which we referred to in discussing JANSSEN'S observation of the apparent interruption of the 1474 line in the spectrum of the prominence.

Relative brightness of the lines seen with integrating spectroscopes.

Of the observers who have made use of integrating spectroscopes, all who refer to the relative brightness of the lines agree that the 1474 line was decidedly the brightest; but PYE and FERGUSON seem to be the only observers who have given numerical estimates of the relative brightness of the lines. When reduced to the same scale, so that the brightness of the 1474 line is represented in each case by 10, their estimates of the relative brightness of 1474 and D_3 are seen to agree fairly, but FERGUSON reverses the order of the brightness of the hydrogen lines, thus—

	1474	C	D_3	F
PYE	10	8·5	5·5	3·0
FERGUSON	10	6·66	6·66	8·33

YOUNG, in 1871, made use of the relative numbers given by PYE, and calculated that if the light of the 1474 region and the hydrogen region were uniformly distributed, and if the relative brightness of the C and 1474 lines in these regions were assumed to be similar to the relative brightness of the same lines as seen in the spectrum of the chromosphere, taking the height of the hydrogen region as only 10″, the 1474 region would correspond to a ring of about 10′ in width. But it will be seen that, with our present knowledge, we must vary these data considerably. The height of the hydrogen region must be taken as much greater than 10″, and the relative brightness of the 1474 and C lines cannot be assumed to be the same in the corona as in the prominences. Besides this, we now know that the light of the hydrogen region is by no means uniformly distributed. And from the observation of YOUNG, as well as from that of LOCKYER, with regard to the thickening downward of the 1474 line, we also know that the 1474 light is more intense the nearer we approach to the sun's limb.

Observations referring to the Relative Brightness of the Lines of the Coronal Spectrum as seen with Analyzing Spectroscopes.

1868. **Rayet.** In describing his sketch, Rayet mentions that he intends the thickness of the lines to be proportional to their brightness. The D, E, and F lines are carried upward into the part of the field corresponding to the corona by narrow lines, which appear to be all of about the same thickness.

1870. **Carpmael.** Three lines were seen in the spectrum of the corona—a green line and two other lines—at the extremities of his field of view. He speaks of the green line as "the bright corona line."

Winlock. In carrying the slit to the outer limits of the corona, the 1474 line was found to be "somewhat more persistent" than the other lines.

1871. **Lockyer.** Four exquisite rings. In brightness C came first, then F, then G, and last of all 1474.

In describing his observation with his other instrument, Lockyer states that the 1474 line was very faint throughout its length compared with what he had expected; and he implies, though he does not definitely state, that it was not as bright as the lines of the hydrogen spectrum.

Respighi. The green zone surrounding the disc of the moon was the brightest. The red zone was also very distinct, while the blue was the faintest.

Observations referring to the Relative Brightness of the Lines as seen with Integrating Spectroscopes.

1869. **Pickering.** Two or three bright lines were seen—the brightest in the neighbourhood of E.

1870. **Abbay.** F, and another line (rather brighter than F) was seen on the less refrangible side of *b*.

Pye. The estimated relative brightness of the lines was: C, 8·5, D_3, 5·5, 1474, 10·0, F, 3·0.

1871. **Tupman.** I saw one bright green line, which I knew to be 1474, and several others extremely faint.

Ferguson. Reckoning the intensity of the 1474 line as 6, I should ascribe to the rest the following numbers: A (= C ?) 4; D (or near D) 4; the line $\frac{1}{8}$ between D and 1474, 3; the line $\frac{1}{4}$ between D and 1474, 3; the line $\frac{3}{8}$ between D and 1474, 1; 1474, 6; the line slightly more refrangible than 1474, 3; F, 5.

With regard to the actual intensity of the bright lines of the coronal spectrum we have very little evidence to guide us. MACLEAR, in 1871, was unable to detect any spectrum from any part of the corona, with a

Absolute intensity of the bright lines of the spectrum of the corona.

telescope and spectroscope with which he had been able on the nights immediately before the eclipse to see three lines in the spectrum of the nebula in the sword-handle of Orion. There can be little doubt that his instrument was properly adjusted, and that he was able to point it with sufficient accuracy; for only a few seconds before he had observed the reversion of the lines at the east limb—an observation which requires considerable accuracy in directing the telescope. He expresses some little doubt with regard to the width of the slit on the two occasions, but adds that when observing the nebula the lines "were narrow and distinct." Possibly, at the beginning of totality, his eye may have been somewhat dazzled by the brilliant spectrum of the cusps and by the reversal of the lines which he had just been observing; but towards the end of totality, which lasted more than two minutes, his eye must have greatly recovered its sensitiveness. But though he continued to observe throughout totality, and carried his slit to all parts of the corona, pointing his instrument "carefully close to the moon," he was unable to perceive any trace of light in the field of his spectroscope. No particulars are given respecting the diameter of the prisms or the aperture and focal length of the collimators and telescopes, and the powers he made use of with his spectroscopes, so that we have no means of determining whether the whole pencil was utilized; but it seems probable that there was a serious loss of light from some cause, for it will be seen, on referring to the table given at the end of this section, that the intensity of the image thrown upon the slit plate was greater with each of the instruments used by MACLEAR than with that made use of by YOUNG in observing the faint corona of 1870. And while MACLEAR made use of a battery of six prisms of 60° with one instrument, and a seven-prism direct-vision spectroscope with the other, YOUNG used a battery of compound prisms, with a dispersive power equivalent to thirteen prisms of 55° each, which must have absorbed a great deal more light than either of the spectroscopes used by MACLEAR; but YOUNG, nevertheless, traced the 1474 line to a distance of 16′ from the limb. Whatever was the cause of the loss of light, MACLEAR'S observation shows that the monochromatic light of the corona is not strong compared with that emitted by the nebula in Orion.

That the monochromatic light emitted by the corona forms only a small part of the total light, is proved by the strong polarization of the

light of the corona, which would certainly be masked if the light emitted by incandescent gas bore a large proportion to the dispersed solar light. But the very small proportion of monochromatic light is still more strongly proved by the fact that so many of the spectroscopic observers have seen the continuous spectrum of the corona and yet have failed to detect any trace of bright lines.

It will be seen that with a moderately narrow slit a very small percentage of monochromatic light would make itself apparent as a brighter line upon a faintly illuminated field. The greater the dispersion the more easily would such monochromatic light be perceived. But Pogson, the dispersion of whose instrument is not mentioned, Riha, Tennant, and Brown, each using one prism of 60°, Winlock in 1869, using two prisms, and Perry in 1870, using three compound prisms, equivalent to four or five prisms of 60°, all failed to observe the bright lines, although they describe the fields of their spectroscopes as being occupied by faint continuous spectra, bright enough in some instances to show colours.* These observations and the brightness of the continous spectrum seen by nearly all the spectroscopic observers seem to indicate that the proportion of monochromatic light emitted by the gaseous matter of the corona is very small compared with the total light of the corona.

Attempt to photograph the spectrum of the corona.

An attempt was made during the eclipse of April, 1875, to photograph the spectrum of the corona, but, as might have been expected,† the attempt failed, and only images of the prominences and the bright erupted matter of the chromosphere were obtained. The total light of the nebula of Orion has never yet, even with long exposures, left any trace upon photographic plates. We are very far, therefore, from obtaining a photograph of its spectrum. It will be remembered that the light which passes between the jaws of the slit of a spectroscope is not only dis-

* We must not omit to mention that dispersed sunlight entering the instrument in front of the slit would give a spectrum with Fraunhofer lines, while dispersed sunlight or the light of a lamp falling on the prisms or entering the instrument behind the slit would give rise to an illuminated field such as is described.

† See a letter "On the Brightness of the Corona," which appeared in the *Athenæum* of May 8th, 1875. The letter was also printed in the *Astronomical Register* for May 1875. See also the report of a discussion which occurred at the January meeting of the Royal Astronomical Society, and which was published in the February number of the *Astronomical Register* for 1875.

tributed over the whole length of the spectrum, but each monochromatic image of the slit is considerably weakened by reflexions from the surfaces of the prism or prisms and lenses, as well as by absorption from the glass of which they are composed.

Some seconds are required to obtain a photographic record of the brighter parts of the corona, even with short-focused instruments,* like those with which the Syracuse and Indian photographs of 1871 were taken; and when we bear in mind the extreme faintness of the spectral images compared with the total light of the corona, it will be seen that there is but little chance of obtaining a record of the lines † of the coronal spectrum by means of the photographic processes at present in use.

Green coronal line seen after totality.

After totality is over, some seconds elapse ‡ before the green line of the corona is drowned by the brightness of the spectrum of the increasing light dispersed by our atmosphere. But this does not prove, as has been supposed, that the green coronal line is bright compared with the light of the photosphere dispersed by our atmosphere. We should expect to find that the brightest part of the coronal spectrum would be the last to be lost sight of in the spectrum of the increasing sunlight; and it will also be seen that the brightest part of the coronal spectrum would be visible after the total light of the corona, as seen with the naked eye or with a telescope, had been drowned by the increasing sunlight dispersed by our atmosphere.

* No photograph of the *corona* has yet been obtained which has not been taken in the principal focus. Secondary focus photographs have in no instance shown anything above the prominences. It will be seen that photographs of the spectrum of the corona must necessarily be taken in a secondary focus; for, in order to avoid the effects of diffraction, as well as to obtain the maximum amount of light, the slit must be placed in the principal focus.

† It is, perhaps, hardly necessary to point out that the monochromatic images which have been seen without a slit cannot be brighter than the elementary portions of them isolated by a slit, and that the spectrum of a large object like the corona observed without a slit must be *very* impure. It is true that, without a slit, overlapping spectral images of the corona might be thrown upon a photographic plate in the principal focus; but we question whether the impurity of the spectrum would not much more than counterbalance other advantages.

‡ Nobile, in 1870, says that the green line was visible for 15 seconds after totality: "Debbo aggiungera che la riga brillante veduta nella corona non spari al momento della ricomparizione del lembo solare, ma andò gradatamente spegnendosi durante circa 15 s. dopo la fine della totalità." Moseley, in 1871, says, "I was surprised to see 1474 still bright, and I watched it for nearly half a minute, till it disappeared."

Comparison of Instruments made use of in observing the Spectrum of the Corona.

The following list refers only to observers who have made use of analyzing spectroscopes. It shows the aperture and focal length of the telescopes they have employed to throw the image of the corona upon the slit plates of their spectroscopes, and gives, as far as we have been able to ascertain them, the optical constants of the spectroscopic combinations they have employed.

The number following the aperture and focal length of the telescope shows the intensity of the image thrown upon the slit plate as compared with the intensity of the image which would be thrown by an object-glass whose aperture is one-tenth of its focal length. Only a few of the observers give the particulars which are necessary to enable us to determine whether the whole pencil passing through the jaws of the slit was utilized; but it will be noticed that the results obtained do not by any means correspond with the intensity of the image falling upon the slits of the spectroscopes. It seems, therefore, to be probable that in many instances much of the light must have been lost. It may be well here to point out some of the chief conditions which must be attended to in order that the whole pencil received from the object-glass of the telescope may be utilized. 1. The collimator and telescope of the spectroscope must be at least as short focused in comparison with their aperture as the telescope used to throw the image upon the slit. 2. The size of the prisms must be sufficient, and their position with respect to the collimator and telescope must be such, as to permit of the transmission of the whole beam received from the collimator. 3. The power used upon the telescope of the spectroscope should be such that the whole pencil from the object-glass just enters the pupil of the eye as expanded during the comparative darkness of totality. The intending observer might, in order to determine the most suitable power to make use of, measure the diameter of the pupil of his eye as expanded in observing the spectrum of a star—say at about 60° from the moon—upon a bright moonlight night. If the diameter of the beam passing through the prisms were one inch, and the diameter of his expanded pupil were, say, one fifth of an inch, the most suitable power to make use of would be a power of five.

List of Instruments made use of in observing the Spectrum of the Corona.

1868. **Riha.** Lens throwing image on slit aperture 5 in., focal length 9¼ in. (?) Intensity of image, 29·2. (The intensity of the image thrown by a lens of aperture one, and focal length ten, being counted as unity.) Focal length and aperture of collimator and telescope of spectroscope not given. Power on telescope about 20. One flint-glass prism of 60°. [*Continuous spectrum observed.*]

Janssen. Four telescopes of 6 in. aperture; spectroscopes with different powers. Other particulars of instruments not given. [*Continuous spectrum.*]

Tennant. Telescope 4·6 in. aperture, 60 in. focus. Intensity of image 0·59. Particulars as to collimator and telescope of spectroscope not given. One prism. Illuminated scale. [*Continuous spectrum.*]

Pogson. Instrument not described. [*Continuous spectrum.*]

Herschel. Telescope 5 in. aperture, 62 in. focus. Intensity of image 0·65. One prism of 60°. Particulars as to collimator and telescope of spectroscope not given. [*No trace of continuous spectrum.*]

Rayet. 8-in. reflector, focal length not given; but it is mentioned that the aperture and focal length of the collimator were such that the whole pencil received from the mirror was utilized. Direct-vision spectroscope of 3 prisms. Power used with spectroscope not mentioned. [*Three lines seen in the spectrum of the corona, extending to a height of nearly* 7′.]

1869. **Harkness.** Telescope 3·01 in. aperture, 43·58 in. focal length. Intensity of image 0·47. Collimator and telescope of spectroscope such that the whole pencil would be transmitted. Power made use of was such that the whole pencil would enter the eye if the diameter of the pupil were only ·079 of an inch. (A lower power might, no doubt, have been made use of with advantage.) One prism of 60° 8′. Illuminated scale. [*Continuous spectrum, and green line at a height of about* 5′.]

Young. Telescope 4 in. aperture, 30 in. focal length; image enlarged to 2·125 in. diameter. Intensity of image less than 0·03. Collimator and telescope of spectroscope such that the whole pencil would be transmitted. A power of 18 was made use of. (The whole pencil would have entered the eye if a power of only 2 had been made use of.) A train of 5 prisms of 45° each. [*Faint continuous spectrum,* 1474, (*and two fainter lines*) ?]

Winlock. Telescope 7·5 in. aperture, 114 in. focal length. Intensity of image 0·43; two flint-glass prisms. Other particulars respecting spectroscope not given. [*Faint continuous spectrum.*]

1870. **Carpmael.** Telescope 5·25 in. aperture, 76 in. focal length. Intensity of image 0·477. Apertures of collimator and telescope of spectroscope not given. Length of collimator 13 in. A power of 5 was made use of. (Assuming that the telescope of the spectroscope received the whole pencil, and that, like the collimator, it was 13 in. in focal length, the whole pencil would have entered Carpmael's eye if his pupil was expanded to 0·18 of an inch during totality—a supposition which is by no means improbable.) One prism of 60°. (Observation made through cloud.)

[*Green line and two other lines at the extremities of the field, traced to a height of* 8′.]

Brown. Telescope 6 in. aperture, 72 in. focal length. Intensity of image 0·69. One prism of 60°. Other particulars respecting spectroscope not given. (Observation made through cloud.)

[*Continuous spectrum observed to a height of* 25′.]

Maclear. Telescope 4 in. aperture, focal length not given. Five-prism direct-vision spectroscope. Other particulars respecting spectroscope not given. (Observation made through cloud.)

[*The bright lines C, D, E, b, F, observed at* 8′ *from the limb.*]

Winlock. Telescope aperture 5·25 in., about 72 in. focal length. Intensity of image about 0·53. Two flint-glass prisms. Other particulars respecting the optical constants of the spectroscope not given (Observation made through cloud.)

[*Bright lines C, D,* 1474, *and F traced to nearly* 25′ *from the limb.*]

Young. Telescope 0^m 162 aperture, 2^m 64 focal length. Intensity of image 0·376. Collimator and telescope of spectroscope such that the whole pencil would be transmitted. Power made use of not given. Battery of prisms having a dispersive power equivalent to 13 prisms of 55° each. (Observation made through cloud.)

[1474 *traced to* 16′ *from the limb.*]

Burton. Telescope 5 in. aperture, focal length not given. Two right-angled prisms. Other particulars respecting spectroscope not given. (Observation made through cloud.)

[*Green line and faint continuous spectrum.*]

Denza. Telescope 10·8 cm. aperture, and 1^m 624 focal length. Intensity of image 0·442. One flint-glass prism of 60°. Other particulars respecting spectroscope not given. (Observation made through clouds.) [*Green line and line near* 1246.]

Harkness. Same telescope and spectroscopic combination as in 1869. (Observation made through clouds.)

[1474 *traced to* 10′ *or* 15′ *from limb; two faint green lines observed for an instant.*]

Lorenzoni. Telescope 11 cm. aperture, focal length not given. Direct-vision spectroscope, with illuminated scale. Other particulars respecting spectroscope not given. [*Green line in the midst of a greenish band.*]

Nobile. Telescope 17·5 cm. aperture, focal length not given. Spectroscope with one prism; particulars respecting collimators and telescope of spectroscope not given. [*Green line observed.*]

1871. Lockyer. Reflecting telescope 9·5 in. aperture, focal length about 6 ft. Intensity of image about 1·74. Collimator and telescope of spectroscope such that the whole pencil would be transmitted. Power made use of not given. One prism of 60°.
[*Vivid hydrogen spectrum, and* 1474 *to a height of about* 7′.]

Lockyer. Instrument No. 2. Naked eye and 5 prisms of 45° of not very dense flint glass. [*Images corresponding to C, F, G, and* 1474, *not more than* 2′ *high.*]

Maclear. Instrument No. 1. Telescope 6 in. aperture, 8 ft. focal length. Intensity of image 0·39. 6-prism spectroscope. Particulars respecting collimator, telescope of spectroscope, and power used, not given. [*Nothing could be seen.*]

Maclear. Instrument No. 2. Telescope 6 in. aperture, 6 ft. focal length. Intensity of image 0·69. A 7-prism direct-vision spectroscope. Other particulars respecting spectroscopic combination not given.
[*Nothing could be seen.*]

Janssen. Reflecting telescope, 38 cm. aperture, and 1^{m} 42 focal length. Intensity of image 7·161. M. Janssen mentions that the focus of the collimator was such that the whole pencil would be transmitted. Power made use of with spectroscope not given. Two direct-vision prisms of five prisms each.
[*Hydrogen spectrum and* 1474 *seen at* 10′ *from limb; dark lines seen in continuous spectrum at* 3′ *to* 6′ *from limb.*

Herschel. } Tennant. } Telescope, 6 in. aperture, focal length 75 in. Intensity of image 0·64 about. Spectroscopic combination constructed to utilize the whole pencil (but the particulars are not given). One compound prism. [1474 *traced to nearly* 20′ *from limb.*]

Respighi. A flint-glass prism of small angle placed in front of a 4·5 in. refracting telescope. Power of 40 made use of.
[*Zones corresponding to C, F, and* 1474 *seen extending to a height of* 6′ *or* 7.]

Moseley. Telescope 3·5 in. aperture, 33 in. focal length. Intensity of image 1·125. Direct-vision spectroscope of five prisms. Collimator and telescope of spetroscope such that the whole pencil would be transmitted. A power of about 40 was made use of. (The whole pencil would have entered Moseley's eye if a power of 3 had been made use of, and the diameter of his pupil during the observation had been 0·18 of an inch.) [1474 *traced to* 22′ *from the limb.*]

1874. Stone. Telescope 4 in. aperture, focal length not given. A Browning star spectroscope, with two dense prisms of 60°. Other particulars respecting spectroscopic combination not given.
[1474 *traced to at least* 45° *from the limb. Hydrogen lines and dark lines seen in the spectrum of the inner corona.*]

[The woodcuts of spectra and the diagrams showing the positions of the slit given in the present chapter have been constructed from the descriptions of the observations printed in the text; and unless it is especially stated that a particular diagram has been submitted to the observer and approved of, the diagram must not be received as embodying any additional evidence with regard to his observation.]

Professor Forbes. [No place given.]
15th May, 1836.

"Comptes Rendus," Tome ii., p. 576.

Instrument—Not described.

Vous savez qu'il y a transversalement dans le spectre solaire, un grand nombre de lignes ou d'espaces entièrement noirs. Ainsi il manque dans la lumière de cet astre, des rayons de certains degrés de réfrangibilité. Ces rayons ne sont absorbés ni par le prisme, ni par l'atmosphère terrestre. Sir D. BREWSTER suppose que cette perte de rayons s'opère dans l'atmosphère du soleil. Dans cette hypothèse, les rayons provenant du bord du soleil ayant à traverser une plus grande épaisseur d'atmosphère, devraient, décomposés par le prisme, présenter plus de lignes ou des lignes plus larges que les rayons émanant du centre. La dernière éclipse de soleil m'a donné le moyen de me procurer un spectre engendré exclusivement par les rayons du bord du soleil; or j'ai reconnu, sans équivoque, que ce spectre est parfaitement identique à celui qui résulte de l'ensemble de la lumière de l'astre. Conséquemment les rayons manquants ne sont pas perdus dans l'atmosphère solaire.

The spectrum derived from the thin solar crescent found to be identical with the ordinary solar spectrum.

M. Fusinieri.

45° 35′ N. } VICENZA,
11° 35′ E. } 8th July, 1842.

"Annuaire du Bureau des Longitudes" for 1846, p. 333.

Instrument—A glass prism (query) used without a slit.

M. FUSINIERI, de Vicence, décomposa, à l'aide d'un prisme de verre, la lumière de l'auréole lunaire. Il assure que le spectre provenant de cette décomposition manquait absolument de vert; et que la place qu'occupe ordinairement cette couleur était entièrement obscure.

Green found to be absolutely wanting in the spectrum of the corona.

Prof. Magrini.

45° 25′ N. } MILAN,
9° 11′ E. } 8th July, 1842.

"Annalen der Sternwarte in Wien," Vol. XXII., p. xxxviii.

Instrument—Prism of flint glass (query used without a slit).

Spectrum of the corona observed for a moment, and found to show, without any doubt, the three colours of Brewster.

Das Spectrum der Aureola, welches ich durch einige Augenblicke mit einem Prisma von Flintglas untersuchte, zeigte ganz entschieden die drey Farben Brewster's.

Mr. Dunkin.

59° 54′ 5″ N. } CHRISTIANIA,
10° 43′ 28″ E. } 28th July, 1851.

"Memoirs of the R. A. S.," Vol. XXI., pt. i., p. 12.

Instrument—Two glass prisms, used without a telescope.

No defect in the prismatic colours noticed.

My observations of the corona are very unsatisfactory; of all the phenomena the clouds affected it most. Traces of it were seen on the whole of the apparent east limb, but on the opposite side of the moon only confused patches of light were visible. . . . . nor could any defect in the prismatic colours be noticed,* green being certainly as bright as any other colour.

Professor William Pole.

42° 27′ N. } HILL OF LA CANTABRIA, near Logroño,
2° 30′ W. } 18th July, 1860.

MS. Reports of the Himalaya Expedition.

Prof. Pole is colour-blind. The prominences appeared to him as colourless. There is only one hue of red which appears colourless to his eye. This has been identified by him as a crimson, rather inclining

I was particularly desirous to ascertain what colour the prominences would appear to me, from the fact of my being colour-blind; and my remarks on this subject must be taken in connexion with my paper, published by the Royal Society in a late volume of the "Philosophical Transactions," describing the peculiarities of my vision.

They appeared to me quite white and colourless, of the same hue as

* Mr. Dunkin informs us that his observation was the work of only a few seconds. It was a hasty glance through a prism applied to the naked eye. No one of his party had any appliance for observing the spectrum with a slit in the modern fashion. He thinks it very possible that the spectrum observed was not that of the coronal light, but rather that of the clouds or sky near the sun.

the corona. It did not occur to me to note particularly at the time, by what property they were so easily distinguishable from their background; but I believe their light was not only brighter, but more compact—their clear forms standing out distinctly defined on the more nebulous ground of the corona. I am quite sure they appeared neutral and colourless to me, neither inclining to yellow nor blue, for slight tinges of which my eye is very sensitive.

to violet. It is not contained in the spectrum, but lies among the hues which are wanting to connect the red and violet ends together.

Now it will be seen from my paper that, according to the nature of my vision, there is only one particular hue of red which complies with this condition. And it appears to me therefore a fair inference that this hue represents the true colour of the prominences. It has been identified as a crimson rather inclining to violet, not much different from crimson lake; and it nearly corresponds with the colour marked Red Violet on the "Cercle chromatique" published by M. Chevreul.

This colour, of which the prominences would probably be a light or pale tint, has some peculiar properties. It is not contained in the spectrum, but lies among the hues which are wanting to connect the red and violet ends together, and make the image re-entrant; the red end conveys a decided sensation of yellow, the violet end a decided sensation of blue; nor, as far as I know, is the colour produced by polarization, nor can it be exhibited by coloured glasses; indeed, I do not recollect ever having seen any direct red light of this hue until I saw these prominences upon the sun.

M. Barreda.

40° 5′ N. } DESIERTO DE LAS PALMAS,
0° 0′ long. } 18th July, 1860.

"Über Totale Sonnenfinsternisse," Dr. von Mädler (p. 28).

Instrument.—A prism of flint glass placed opposite an opening in the wall of a room.

Sein Standpunkt war ein Zimmer in der Eremitage S. Juan, wo er das Spectrum der Sonne untersuchte. Das Licht fiel durch eine Maueröffnung, in der eine sehr reines Flintglasprisma angebracht war. Es war senkrecht zwischen Oeffnung und Fernrohr angebracht.

Spectrum light from the heavens observe during totality; only a trace of green and red were visible.

20^m nach dem Anfange der Finsterniss zeigte sich eine beträchliche Verwirrung im Spectrum; bei 30^m fing das Roth an, allmählich zum Weiss abzubleichen, während Gelb und Grün in einander flossen und in eine

gemeinschaftliche gleichförmige Mischfarbe übergingen; nach 40^m zeigte sich dasselbe mit Blau und Indigo. Die Vermischung nahm je länger desto mehr zu. Orange und Violet blassten ab; nach 50^m war das Orange ganz verschwunden, eben so das Violet 5^m vor der Totalität; dann verschwand auch Indigo und vom Blau blieben nur schwache Spuren.

Observation during totality.

Beim Eintritt der Totalität blieb nichts als einige Spuren von Grün und Roth; alles andre war ganz verschwunden. Nach dem Wiedererscheinen der Sonne wiederholte sich alles Vorstehende in umgekehrter Ordnung.

Linienschiffsfähnrich J. Riha.*

12° 45′ N. } ADEN,
45° 3′ E. } 18th Aug., 1868.

Sitzb. d. wien Akad. d. Wissensch. lviii. Bde. ii. Abth. Oct-Heft. 1868.

Instrument.—The light reflected from a heliostal was collected by a condensing lens of 5 inches aperture and (9¼† ?) inches focus, upon the slit of a spectroscope, with one prism of flint glass of 60°. The focal length and aperture of its collimator and telescope are not given; but the telescope had a power of about 20.

At the beginning of totality the ordinary spectrum suddenly changed to a faint continuous spectrum, in which no dark lines were seen. No bright lines were observed. For three or four seconds before the end of totality a discontinuous spectrum was observed, which (though the description is not very clear) seems to have been a bright-line spectrum corresponding to the base of the chromosphere on the western limb.

(p. 721.) Nach mehrfachen Versuchen auf der k. k. Sternwarte mit Spektroskopen verschiedener Art beschlossen wir einen Bunsen'schen Spektralapparat einfachster Construction mit nur einem Flintglasprisma anzuwenden, weil uns bei dem Mangel eines jeden sicheren Anhaltspunktes über die Helligkeit der Corona ein gegen schwache Lichtintensitäten möglichst empfindlicher Apparat wünschenswerth schien. Das Flintglasprisma hatte einen brechenden Winkel von 60° und das mit einem Ocularmikrometer versehene Fernrohr beiläufig eine 20 fache Vergrösserung. Auf die Spalte wurde das Licht durch einen Heliostaten geworfen, der nach den Angaben des leider früh verstorbenen Otto von Littrow construirt ist, und sich vorzüglich bewährte. Zwischen den Heliostaten und die Spalte wurde noch eine Sammellinse von 5 Zoll Öffnung eingeschaltet, um das auf die letztere fallende Licht möglichst zu concentriren. Bei dieser Zusammenstellung liefert, wie

* In the account of the Aden expedition given in the Vierteljahrsschrift for July, 1872. (VII. jahrgang, Drittes heft) Herr Riha's name is spelt as Rziha. Weiss in his summary of the observations of the eclipse of 1868, also spells it Rziha.

† The image of the elipsed sun upon the slit is said to have been about a line in diameter. The focal length of the condensing lens must therefore have been about 9½ inches.

man leicht einsieht, die Corona während der Totalität die Hauptmenge des Lichtes zur Bildung des Spektrums. Nach unserer Ankunft in Aden rektificirte ich meine Instrumente auf das sorgfältigste, und begann sofort die Aufstellung derselben die ich von nun an, an jedem folgenden dazu geeigneten Morgen genau controllirte, um am Tage der Finsterniss jeden sich zeigenden Sonnenblick auf's beste benützen zu können. Es ging auch in der That so wie wir es vermuthet hatten, am Tage der Finsterniss die Sonne ganz hinter Wolken auf, und trat erst beiläufig eine Viertelstunde vor dem Eintritte der Totalität auf kurze Zeit in eine kleine Wolkenlücke. Dieser Moment genügte zur scharfen Einstellung des Heliostatenspiegels, und ich erwartete nun, bei jedem Hervorbrechen der Sonnensichel durch die Wolken das Spektrum derselben untersuchend, mit Spannung den Eintritt der totalen Verfinsterung. Da ich aber bei der Anordnung meines Apparates der Sonne den Rücken zuwendete, hatten wir verabredet, dass Dr. Th. Oppolzer mir durch einen kurzen Zuruf den Augenblick des Eintretens der Totalität anzeige, damit ich um jene Zeit nicht nöthig hätte das Auge vom Fernrohre zu verwenden, sondern ruhig die im Spectrum eintretenden Veränderungen verfolgen und doch auf gar keinen Fall über den Beginn der vollständigen Verfinsterung im Zweifel sein könnte. Doch hätte es, wie sich später zeigte, dieser Vorsicht nicht erst bedurft, denn es war auch im Spektroskope dieser Augenblick nicht zu verkennen.

Description of instrument.

Es zeigten sich nämlich bei der raschen Verkleinerung der Sonnensichel im Spektrum ausser der Abnahme seiner Helligkeit keine Änderungen, sobald aber der letzte Lichtstrahl der Sonne verschwand, verchwanden

Diagram to illustrate the spectrum observed by Riha.

auch momentan alle Fraunhofer'schen Linien, und es ging das Spektrum mit einem Schlage in ein continuirliches über. Eine eigentliche Umkehrung desselben konnte ich nicht erkennen, da ich trotz aller Anstrengung des Gesichtes nicht eine einzige helle Linie wahrnahm. Als ich die Spalte nach und nach vergrosserte, verzerrte sich das continuirliche Spektrum, und nahm an Deutlichkeit ab, gerade so wie diess bei gewöhnlichem Lichte eintritt wenn die Spalte zu gross gemacht wird.

Observation at the beginning of totality.

Riha's observation.

Das Verschwinden der dunklen Linien kann ich nicht dadurch erklären, dass die Lichtquelle vielleicht zu schwach gewesen wäre, denn bei früher angestellten Versuchen sah ich bei einem noch viel schwächeren Spektrum wenigstens noch die wichtigsten Linien, namentlich die Linien D. und E. jetzt aber gar keine. Um mich zu vergewissern, dass alles in Ordnung sei, blickte ich auf die Spalte, und sah dass die oben erwähnte Sammellinse auf die schwarze Fläche derselben ein sehr scharfes Bild der verfinsterten Sonne von beiläufig einer Linie im Durchmesser projicire, man erkannte ganz deutlich den schwarzen Kern, der ringsherum von der Corona umgeben war. Der Anblick des Spektrums blieb bis gegen das Ende der Totalität der gleiche. Als aber kurze Zeit ehe der erste Lichtstrahl wieder zum Vorschein kam, über die verdunkelte Sonnenscheibe dünne Wolken dahinzogen, welche den grossten Theil der Corona verdeckten, und in Folge dessen die Protuberanzen nebst dem beim Ende der Totalität ercheinenden hellen rothen Saume die hauptsächlichste Lichtquelle bildeten, ging im Spectrum eine merkwürdige Änderung vor. Es verschwanden nämlich in demselben nach und nach vom Grün an, alle Strahlen grösserer Brechbarkeit, und es blieben nur die am rothen Ende übrig. Am hellsten waren Hochroth, Carminroth und Orange sichtbar. Gelb schon viel schwächer und grün kaum noch bemerkbar. Ausserdem verwandelte sich dieser Rest des Spectrums in ein discontinuirliches, indem grössere dunkle Streifen darin auftraten, welche mir jedoch nicht mit irgend einer Hauptlinie des Spectrums im Einklange zu stehen schienen. Die einzelnen oben genannten Farben waren jede für sich genommen gleich intensiv, während die Helligkeit derselben von Roth gegen Grün hin abnahm; dasselbe gilt von den sie trennenden dunklen Streifen, welche überdiess viel matter vorgefunden wurden, als die des gewöhnlichen Spectrums.* Diese dunklen Streifen hatten beiläufig die Breite der Linie D. Eine Messung der gegenseitigen Lage der dunklen Streifen mittelst des Ocularmikrometers konnte ich leider nicht vornehmen da die ganze zuletzt geschilderte Erscheinung blos 3 bis 4 Secunden dauerte; dann brach das Sonnenlicht hervor; und das Spectrum ging sogleich wieder in das gewöhnliche Sonnenspectrum über.

Observation towards the end of totality.

* We have not referred to this observation of Ensign Riha on pp. 337-8, as his meaning is not very clear, and the place of his slit at the end of totality is not given; but it seems probable that his observation corresponds to Young's observation in 1870, of the bright line spectrum of the reversing layer.

Capt. C. T. Haig.

16° 50 N. } BEEJAPOOR,
75° 48′ E. } 18th Aug., 1868.

Proceedings of the Royal Society, *Recess*, 1868.

Instrument—A small direct vision spectroscope, used without a slit (query).

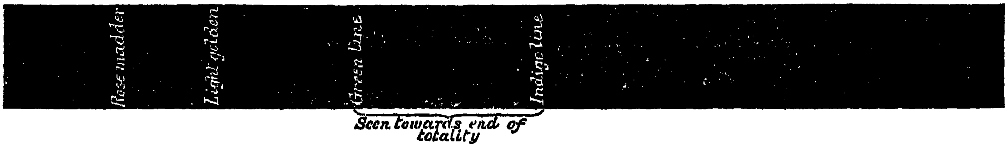


Diagram to illustrate Haig's observation.

(p. 74.) I may state at once that I observed the spectra of two red flames close to each other, and in their spectra two broad bright bands quite sharply defined—one rose-madder and the other light golden. These spectra were soon lost in the spectrum of the moon's edge just before emergence, which had also two well-defined bright bands (one green and one indigo), about a quarter the width of the bands in the spectra of the flames, this spectrum being again soon lost in the bright sunlight. . . . .

Two bright bands—one rose-madder and the other light golden. Just before the end of totality two additional lines seen—one green and one indigo.

I had one of the Royal Society's small hand-spectroscopes, and a small 6-inch transit theodolite by Troughton and Simms, the cap of the object-glass of which I had cut so as to receive the prism-cap of the spectroscope, and had fitted one to the other, so that I could at once shift the prism-cap from its own telescope to that of the theodolite, and *vice versâ*. . . . .

In the diaphragm of the theodolite-telescope I had a system of wires, which I had intended for assistance in general observations of the flames, in case I should find I could make no satisfactory spectrum-observations—which, from the absence of any slit arrangement in the spectroscope, I was rather inclined to anticipate. . . . .

(p. 76.) I saw through the naked telescope of the small theodolite that red flames were visible, and at once pointed the spectroscope,* using the theodolite-telescope as a rest. Very fortunately, I directed the spectroscope with its "refracting edge" tangent to the moon, where two red flames

* Mr. Ladd informs us that the spectroscopes sent out by the Royal Society were small direct-vision integrating instruments. From Capt. Haig's account it appears that the slit plate of his spectroscope was missing.

Haigh's observations.

were protruding, separated from each other by a small interval, so that their spectra, which were identical, were extended over the dark background of the moon's disc, and stood out in most brilliant contrast with the feeble but continuous * spectrum of the corona; and in their spectrum there were the two broad bright bands I have above described. Most fortunately, also, these red flames were on that part of the sun which first reappeared, so that just before or just at emergence there appeared on the very part I was intently observing one brilliant wide spectrum with the green and indigo bands before described, remaining visible for an interval just long enough to enable me to make quite sure of the position of the bands which were then obliterated by the bright light of the sun.

M. Janssen.

16° 20′ N. } GUNTOOR,
80° 30′ E. } 18th Aug., 1868.

"Comptes Rendus" † for 15th Feb., 1869, pp. 367—375.

Instruments—Four telescopes of 6 inches aperture, spectroscopes with different powers.

Slit tangential at the centre of the disappearing crescent. Two spectra were seen in the field, each composed of five or six brilliant lines. In the red, yellow, green, blue and violet, each spectrum was found to correspond to the section of a prominence. They matched exactly, bright line for bright line.

(p. 368.) Mes instruments consistaient en plusieurs grandes lunettes de 6 pouces d'ouverture, et un télescope Foucault de 21 centimètres de diamètre. Les lunettes étaient montées sur un même plateau qui les rendait solidaires. Le mouvement général était communiqué par un mécanisme construit par MM. Brunner frères, qui permettait de suivre le soleil par un simple mouvement de rappel. L'appareil était muni de chercheurs de 2 pouces et 2¾ pouces d'ouverture, formant eux-mêmes de bonnes lunettes astronomiques.

En analyse spectrale céleste, les chercheurs ont une importance toute particulière; c'est par leur intermédiaire qu'on sait sur quel point précis de l'objet étudié se trouve la fente du spectroscope de la lunette principale. Il importe donc que les fils réticulaires, ou en général les points de repère placés dans le champ du chercheur, soient réglés très-rigoureusement sur la fente de l'appareil spectral. Tous mes soins avaient été apportés pour atteindre ce but capital. Des micromètres spéciaux devaient permettre, en

* With no slit and a direct-vision prism of small dispersion the spectral images of the corona would be superposed. We must not, therefore, conclude from the above that Capt. Haig's observations may be taken as evidence in favour of a continuous coronal spectrum.

† See also a preliminary paper by M. Janssen in the "Comptes Rendus," Vol. lxvii., p. 838.

outre, de mesurer rapidement la hauteur et l'angle de position des protubérances. Quant aux spectroscopes adaptés aux grandes lunettes, je les avais choisis de pouvoirs optiques différents, afin de pouvoir répondre aux diverses exigences des phénomènes de l'éclipse. Enfin tout l'appareil portait du côté des oculaires, des écrans en toile noire, formant chambre obscure, et destinés à conserver à la vue toute sa sensibilité. . . . Janssen's observation.

(p. 369.) Pendant les premières phases, quelque légères vapeurs vinrent passer sur le soleil, elles nuisirent à la netteté des mesures thermométriques, mais quand le moment de la totalité approcha, le ciel reprit une pureté suffisante. . . .

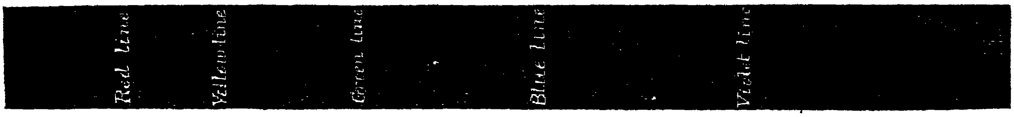


Diagram to illustrate Janssen's observation of the spectra of the prominences.

(p. 370.) Bientôt le disque solaire se trouve réduit à une mince faucille lumineuse. On redouble d'attention. Les fentes spectrales de l'appareil des six pouces sont rigoureusement tenues en contact avec la portion du limbe lunaire que va éteindre les derniers rayons solaires de manière que ces fentes soient amenées par la lune elle-même dans les plus basses régions de l'atmosphère solaire, quand les deux disques seront tangents.

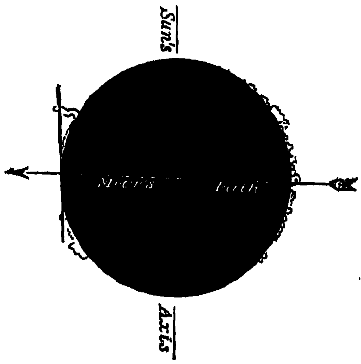


Diagram to show position of slit.

L'obscurité a lieu tout à coup, et les phénomènes spectraux changent aussitôt d'une manière bien remarquable.

Deux spectres formés de cinq ou six lignes très-brillantes—rouge, jaune, verte, bleue, violette—occupent le champ spectral, et remplacent l'image prismatique solaire qui vient de disparaître. Ces spectres, hauts d'environ une minute, se correspondent raie pour raie; ils sont séparés par un espace obscur où je ne distingue aucune raie brillante sensible. Observation.

Le chercher montre que ces deux spectres sont dus à deux magnifiques protubérances que brillent maintenant à droite et à gauche de la ligne des contacts où vient d'avoir eu lieu l'extinction. L'une d'elles surtout (celle de gauche) est d'un hauteur de plus de 3 minutes; elle rappelle la

Janssen's observation.

flamme d'un feu de forge sortant avec force des ouvertures du combustible, poussée par la violence du vent. La protubérance de droite (bord occidental) présente l'apparence d'un massif de montagnes neigeuses, dont la base reposerait sur le limbe de la lune, et qui seraient éclairées par un soleil couchant. Ces apparances ont été décrites avec soin par M. Jules Lefaucheur. Je ferai seulement remarquer, avant de quitter le sujet des protubérances sur lequel j'aurai à revenir d'une manière spéciale, que l'observation précédente montre immédiatement :—

1°. La nature gazeuse des protubérances (raies spectrales brillantes).

2°. La similitude générale de leur composition chimique (spectres se correspondent raie pour raie).

3°. Leur espèce chimique (les raies rouge et bleue de leur spectre n'étaient autres que les raies C et F du spectre solaire caractérisant comme on sait le gaz hydrogene).

Lieut.-Col. Tennant.

16° 17′ 29·23″ N. } Guntoor,
80° 27′ 9″ E. } 18th Aug., 1868.

"Memoirs of the Royal Astronomical Society," Vol. xxxvii., pt. 1.

Instrument—Telescope of 4·6 inches aperture and 5 feet focal length, equatorially mounted, and driven by clockwork. Spectroscope with a comparison scale illuminated by a lamp, and dispersive power of a single prism of flint-glass.

Spectrum of corona undoubtedly continuous. Spectrum of great prominence. C, D, *b*, F or near F, and hazy light probably beyond G.

(p. 15.) The spectroscope had originally been made by Messrs. Troughton and Simms, for the Astronomer Royal's telescope, and had only a single prism of flint-glass. The slit was placed in the focus of an object-glass of short focus and considerable aperture, which made the rays issuing from it parallel. After passing through and being dispersed by the prism, they were viewed as usual by a small telescope, on whose object-glass they fell. To identify any ray, in the absence of a spectrum of comparison, a scale of equal parts was reduced by photography to a small size. This was illuminated by a swinging lamp, and the rays from it having been rendered parallel by an object-glass, were reflected from the surface of the prism up the small telescope. They thus became visible at

* A drawing of the spectroscope is given on plate ix., p. 53 of vol. xxxvii., pt. 1, of the "Mem. R. A. S."

the same time as the spectrum. An arrangement was also provided, by which two plates of metal, close to the jaws of the slit, could be simultaneously moved outwards and inwards by eccentric cams, so that the the length of the slit and breadth of the spectrum could be adjusted with the touch of a finger. The width could likewise be adjusted by a screw which moved one of the jaws.

Tennant's observation.

Diagram to illustrate the spectrum of the corona observed by Tennant.

Spectrum of corona.

(p. 18.) Directly I saw the whole moon in the finder, I set the cross-wires immediately outside its upper* limb. By the time I got to the spectroscope, the cloudy range, seen in the photographs, had vanished from the slit, and I saw a very faint continuous spectrum. Thinking that want of light prevented my seeing the bright lines, which I had fully expected to see in the lower strata of the corona, I opened the jaws of the slit, and repeatedly adjusted by the finder, but without effect. *What I saw was undoubtedly a continuous spectrum, and I saw no lines.*† There may have been dark lines, of course, but with so faint a spectrum, and the jaws of the slit wide apart, they might escape notice.

Spectrum of prominence.

I then searched for the remarkable horn, projecting apparently upwards from the moon's limb. A slight disarrangement of the wires in the

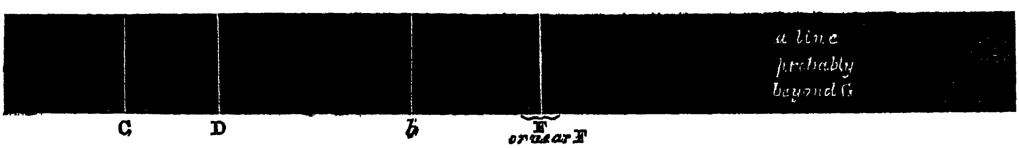


Diagram to illustrate the spectrum of the prominence observed by Tennant.

finder lost me some time; suddenly, however, it burst into sight,—a gloriously brilliant linear spectrum. I closed the jaws of the slit as fast as I could, and hastily cast my eyes over the field. One line in the red was so beautiful that it needed an effort to turn my attention to anything else; there was a line in the orange not so well defined, and one in the green

* Col. Tennant evidently means the upper limb as seen in the inverting telescope.

† *Note by Col. Tennant.*—In the instructions for Lieut. HERSCHEL his attention was first drawn to the protuberances. I therefore had resolved to attend first to the corona, lest each of us should have only the same partial tale.

Spectrum of prominence observed by Tennant.

which seemed multiple (it must be remembered that I had not time to adjust the jaws of the slit accurately, and that the brilliancy of these lines made them broader by irradiation); beyond I saw a line just defined, which . . . . must have been near to F, and still further off, in the blue, I saw a hazy light, probably beyond G.

Adjusting the lamp, I read the red line at 256 divisions, the next at 238, and the green one at 210. While I was endeavouring to make up my mind about the place of the next one, which was hazy, the sun re-appeared, and this spectrum faded from view. At 8 h. 11 m. sidereal time, I read the lines as follows:—

Solar line	C	-	255·6
,,	D	-	237·6
,,	E	-	213·3
,,	*b*	-	208·6 (estimated mean of the three lines).

Up to this time all the adjustments were untouched. The changes of focus of the telescope had not evidently disarranged the scale, which I had always found stable in its adjustment.

The red and yellow lines were evidently C and D; the reading of the green line coincides with that of the brightest line in *b*, instead of the mean of the three lines, which I read as a verification; the line near to F was in all probability F itself; E was certainly not seen by me. The line in the blue it is useless from my data to speculate upon. I must hope that some one else has identified it.

Mr. Pogson.

16° 11′ 33″ N. } MASULIPATAM,
81° 12′ 15 E. } 18th Aug., 1868.

Report of the Government Astronomer upon his observations of the Eclipse of Aug. 1868.

Instrument—No description given.

Slit placed upon the corona: faint light seen, certainly free from either dark or bright lines. Slit placed upon a prominence: five bright lines

(p. 10.) About one minute after the beginning of totality, I directed the finder of the spectroscope telescope to a part of the corona on the sun's southern limb, as clear of any visible prominences as possible. A faint light was seen, scarcely coloured, and certainly free from either dark or

seen,—the positions of the two brightest were measured

bright lines. While wondering at the dreary blank before me, and feeling intensely disappointed, some bright lines came gradually into view, reached

Diagram to illustrate the spectrum of the corona observed by Pogson.

a pretty considerable maximum brilliancy, and faded away. Five of these lines were visible, but two decidedly superior to the rest. A turn of the right ascension tangent rod immediately brought back the welcome lines, and by manipulating it with one hand and the spectroscope micrometer with the other, the readings of the two brightest were secured. It struck me as strange that these brightest lines should appear at a part of the spectrum not corresponding to any very conspicuous dark lines in the solar spectrum; but not having Kirchhoff's chart in my possession, I must leave it for my scientific friends at home to decide upon the interpretation of the measures

Diagram* to illustrate the prominence spectrum observed by Pogson.

obtained. The third line seen, in order of brilliancy, must have been either coincident with or very near the place of the sodium line D, but it was much fainter than the two measured; while the fourth and fifth lines were extremely faint, and about as close as E and *f*, but I estimated them to be somewhere near the position of Fraunhofer's F in the solar spectrum. The fact of bright lines being seen at all, shows that the red prominence which produced them was composed of incandescent gas, but whether similar to any of our known terrestrial elements or otherwise, it would be premature for me to offer any opinion. The red prominence under observation in my spectroscope was not the long one which most other observers naturally singled out for examination, but one of the two seen side by side about the S.E. by E. point of the moon's black disc. I re-measured the seven ordinary lines of the solar spectrum about the same time on the following morning, and also repeatedly since my return to Madras—the

* This diagram is taken from a coloured plate given in Mr. Pogson's pamphlet, at p. 10.

Pogson's observation.

extreme difference in any case being four divisions of the micrometric scale for the lines A and C. The scale numbers (a mean of the two Masulipatam readings) were as follows:—

a = 1513 in the deep red.
C = 1547 in the bright red.
D = 1639 in the yellow.
E = 1782 } both in the green.
f = 1785 }
F = 1873 in the blue.
G = 2055 in the deep blue.

The two bright lines were situated, the most conspicuous at 1743, and the other at 1763.

Capt. John Herschel.

JAMKANDI, INDIA,
18th Aug., 1868.

Account of the Solar Eclipse of 1868 as seen at Jamkandi, in the Bombay Presidency, by Lieut. J. HERSCHEL, R.E., from the "Proceedings of the Royal Society," vol. xvii., pp. 104 to 120.

Instrument—A telescope of five inches aperture, and sixty-two inches focal length. Equatorially mounted, and driven with clockwork. Spectroscope, a single prism of 60°.

Slit nearly radial on the great prominence. Three vivid lines seen—red, orange, blue—with no trace of a continuous spectrum. Position of red line not measured. Orange line found to be near D, and blue line near F.

(p. 105.) The spectroscope consists of a single flint-glass prism with refracting angle of 60°, contained in a cylindrical brass chamber, from which radiate three tubes in such directions as to fulfil the several purposes of—(1) receiving the light to be analyzed; (2) delivering it after refraction and separation to the eye; and (3) admitting external light for reflexion to the eye off the second surface of the prism. The first consists externally of a long connecting-tube for insertion into the telescope, in place of the ordinary eye-tube, where it is grasped in the focussing slide. Internally, it carries a smaller tube, carrying at one end a lens, and at the other, at the principal focal distance of the latter, a beautiful piece of workmanship, by which a slit is obtained, whose sides approach each other equally. Half the length of this slit may be obscured by the intervention of a right-angle prism, which reflects a side-light through it, if required.

(p. 115.) The spectroscope may be inserted and employed with its slit in any direction perpendicular to the optical axis of the telescope. It is therefore competent to the observer to place the slit perpendicular or tangential to the sun's circumference at any point; and there can be no doubt that, were the observations conducted at leisure, it would be desirable to examine the whole circumference in both positions. But the operation of turning the spectroscope is not so very simple a one, but that the advantages and disadvantages of any such proceeding require to be well considered when time is of the first importance. I decided on employing the slit in one direction only—that which corresponded with the diurnal motion. It so happened that this corresponded nearly with the direction of the relative motion of the sun and moon, so that the widest part of the crescent could be made to fall nearly perpendicularly across the slit. The needle (in the finder) and its point accurately represented the direction and centre respectively of the slit; therefore, when the needle-point touched the sun's limb at the centre of the crescent, a solar spectrum of definite width appeared in the field, of which one edge (the right hand) continued stationary, while the other (the left) advanced slowly but perceptibly towards it; the solar spectrum decreasing visibly in width. . . . . Position of slit and pointer.

(p. 113.) During the advance of the moon, and up to the last available moment, I paid particular attention to the collimation (I use the word in its true sense of aim) of the needle-point, being perhaps unnecessarily anxious to avoid my old difficulty of finding my object in the spectroscope. The sharp cusps were well suited to this purpose, and the sun-spots were good tests. I had been fortunate in getting the pointer very exact, and was therefore not troubled with any collimation error to allow for. . . . .

The principal solar lines were measured at intervals during the advancing eclipse. A few minutes before totality, in going over these lines for the last time—the slit being as wide as was allowable for full sunlight (*i.e.* very narrow)—I recorded an increasing brilliancy in the spectrum in the neighbourhood of D,—so great, in fact, as to prevent any measurement of that line till an opportune cloud moderated the light. I am not prepared to offer any explanation of this. The clouds were arranged in two distinct strata; the lower one containing masses hurrying past with the monsoon-current at no great height, the upper consisting of light thirty-scattered cirri, showing very little motion. It is conceivable that the latter may Increasing brilliancy of spectrum in the neighbourhood of D.

Herschel's observation, 1868.

have been obstinately interposed until the time when I remarked the recorded brilliancy, but I cannot say that I should be satisfied with such an explanation. . . . . .

(p. 115.) The spectrum faded out as I was looking, while it had still appreciable width; and I knew a cloud had intervened.

A few seconds more, and the spectrum of diffused light had vanished also, and told me that the eclipse was total, but behind a

Observation during totality.

cloud. I went to the finder, removed the dark glass, and waited. How long I cannot say,—perhaps half a minute. Soon the cloud hurried over, following the moon's direction, and therefore revealing, first, the upper limb with its scintillating corona, and then the lower.

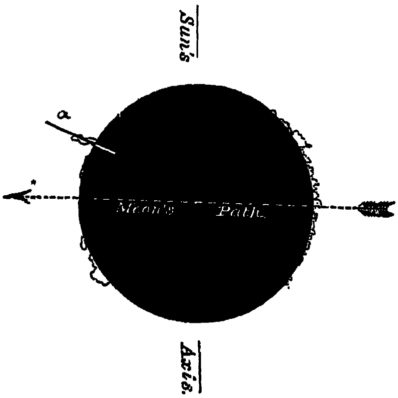


Diagram to show position of slit.

Instantly I marked a prominence near the needle-point,—an object so conspicuous that I felt there was no need to take any precautions to secure identification. It was a long finger-like projection, from the (real) lower left-hand portion of the circumference. A rapid turn of the declination-screw covered it with the needle-point, and in another instant I was at the spectroscope. A single glance, and the problem was solved. THREE VIVID LINES—RED, ORANGE,

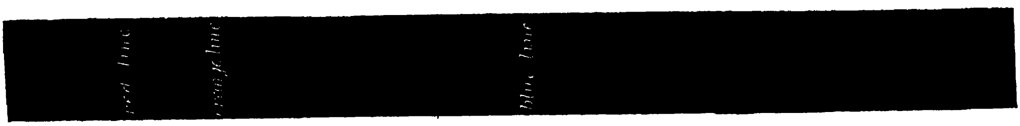


Diagram to illustrate the spectrum of the prominence observed by Herschel.

BLUE; NO OTHERS, AND NO TRACE OF A CONTINUOUS SPECTRUM.* When I say the problem was solved, I am of course using language suited only to the excitement of the moment. It was still very far from solved, and I lost no time in applying myself to measurement. And here I hesitate; for the measurement was not effected with anything like the ease and certainty which ought to have been exhibited. Much may be attributed to haste and unsteadiness of hand, still more to the natural difficulty of mea-

* ABBAY in 1870, and FERGUSON and MOSELEY in 1871, all state that no continuous spectrum was visible. See note on p. 350.

suring intermittent glimpses; but I am bound to confess that these causes were supplemented by a failure less excusable. I have no idea how those five minutes passed so quickly! Clouds were evidently passing continually, for the lines were only visible at intervals—not for one-half the time certainly—and not always bright; but still I ought to have measured them all. My failure was in insufficient illuminating power; but why I cannot tell. I never experienced any difficulty of the kind with the nebulæ, which required that I should flash in light suddenly over and over again. I had found the hand-lamp the surest way; but it failed me here in great measure. The red line must have been less vivid than the orange; for after a short attempt to measure it I passed on to secure the latter. Herschel's observation, 1868.

In this I succeeded *to my satisfaction*, and accordingly tried for the blue line. Here I was not so successful. The glimpses of light were rarer and feebler, the line itself growing shorter, and what remained of it farther from the cross. I did, however, place the cross-wires in a position certainly very near the true one, and got a reading before the re-illumination of the field told me that the sun had reappeared on the other limb. These readings were called out, as those of the solar lines had been, to my recorder, and it was only afterwards that I compared them. . . . . . Two lines measured.

(p. 116.) Almost mechanically I directed the telescope to the bright limb, to verify the readings of the solar lines; and in so doing, my interest was again awakened by the near coincidence, as it seemed, of the line F with the position of the wires; but a little reflection convinced me that the distance of the former was greater than the error which I might have made in intersecting the blue line.

I read F, and then D and C. The following were my readings, up and down:— Their readings, and those of the solar lines.

	C	D	*b*	F
Before	1.91	2.96	4.58	5.64
	1.90	2.94	4.56	5.61
	1.93	2.98	4.60	5.65
	1.92	2.97	4.58	5.62
Bright lines	...	[3.00]	...	[5.56]
After	1.93	3.00	...	5.65

I consider that there can be no question that the orange line was identical with D, so far as the capacity of the instrument to establish any such identity is concerned. Identity of the orange line.

Identity of the blue line doubtful.

I also consider that the identity of the blue line with F is not established. On the contrary, I believe that the former is less refracted than F, but not much.

Of the red line uncertain.

With regard to the red line, I hesitate very much in assigning an approximate place. B and C represent the limits. It might have been near C. I doubt its being so far as B. I am not prepared to hazard any more definite opinion about it. Its colour was a bright red. This estimate of its place is absolutely free from any reference to the origin of the lines C and F. . . . .

(p. 118.) I said that the prominence was situated close to the needle-point. I estimate its position as at the east point, a few degrees to the left of the lowest part of the sun's limb. Its form was that of a projecting finger, slightly curved to the southward, and its height nearly 2′.

Position of slit.

The slit was at right angles to the hour circle, and therefore perpendicular to the sun's limb at this point. A vertical section (so to speak) of the prominence was therefore admitted through the slit. It appears, then, that the length of the lines corresponded with the height of the prominence; being limited (as in the case of the spectrum of the section of the crescent), on the one hand (the left) by the advancing moon's limb at the centre of the field, and on the other by the natural summit of the prominence, or flame, as we are now entitled to call it.

Spectrum of corona not seen

Beyond this summit the light of the corona was free to enter. It was also free to enter *with* that of the flame, but I saw the spectrum of the latter *only*. I thence conclude that the spectrum of the corona was a faint solar one,—a conclusion quite in accordance with the other characteristics of this phenomenon, such as the radiated appearance and the evidence from polarity, indicating a central source of light. . . . . .

At the same time, it is possible that the absence of a spectrum to the corona at this particular spot may have been accidental. I have since heard that the corona was particularly feeble at this point. I had no opportunity of studying the corona myself. After first catching sight of the eclipse in the finder I never left the spectroscope but once, when a long interval of cloudiness sent me to the finder to make sure.

(p. 117.) [Immediately after the eclipse] I went straight to my tent, and tried to write down what I had seen.

M. Rayet.

11° 42′ 35·0″ N. } WHA-TONNE, TANASSERIM,
90° 47′ 45″ E. } 18th August, 1868.

Rapport * sur l'observation de l'éclipse de soleil du 18 Août, 1868, par M. Stephan. 8°. Paris, Imprimerie Imp., 1869. (pp. 23—26.)

Instrument—8 in. reflecting telescope, mounted equatorially, with direct-vision spectroscope of three prisms.

(p. 23.) L'appareil employé pour l'observation spectrale des protubérances se composait d'un télescope à monture équatoriale de 20 centimètres de diamètre et d'un spectroscope à vision direct.

Le miroir en verre argenté avait été parabolisé par M. Martin, suivant les procédés de M. Foucault. Le spectroscope sortait des ateliers de M. Duboscq, et pouvait, à volonté, être remplacé par un oculaire ordinaire. Quoique le système dispersif du spectroscope fût formé de trois prismes seulement, le bon choix des substances, l'excellent travail des surfaces permettaient à l'appareil de dédoubler très-aisément la raie solaire D, et même de faire soupçonner la présence de trois lignes intermédiaires. Le diamètre des prismes, l'ouverture et la longueur focale de la lentille collimateur avaient été déterminés de manière à recevoir toute la lumière qui, concentrée par le miroir, passait à travers la fente; le système oculaire n'offrait rien de particulier. L'ensemble de l'appareil avait une longueur de 40 centimètres, et la fente étant portée au foyer du telescope; la saillie du système était de 30 centimètres seulement.

Un chercheur coudé se trouvait fixé sur la paroi latérale du telescope, et son oculaire venait se placer côte â côte de celui du spectroscope; par un déplacement léger de la tête, l'observateur pouvait porter l'œil gauche dans le chercheur et l'œil droit dans le spectroscope.

From the first moment of totality the spectroscope was directed to the long prominence on the east limb. Nine brilliant lines were seen on an almost black, or rather very obscure violet background. The positions of the lines were not measured, but by their colour and their relative position, they were seen to correspond with B, D, E, *b*, an unknown line, F, and two lines of the G group. The sketch was made in haste at the time, giving to the different lines a thickness proportional to the intensity of their brightness. D, E, and F reached to nearly double the height of their neighbours. The slit was then carried to the west limb, where the same lines, with the exception of one in the violet, were observed.

Un réticule, à plusieurs fils croisés, permettait de déterminer avec exactitude la position à donner au telescope pour qu'un point déterminé du soleil, ou de tout autre astre vînt former son image au centre de la fente du spectroscope.

La fente du spectroscope étant orientée de manière à couper à angle droit l'image du croissant lumineux très-étroit qui devait subsister quelques secondes avant l'obscurité totale. . . . .

(p. 24.) Les observations des éclipses précédentes de 1842, 1851,

* See also "Comptes Rendus," vol. lxvii., pp. 757-9.

Rayet's observation.

et 1860 ayant laissé beaucoup d'incertitude sur l'intensité lumineuse des nuages roses, j'ai cru devoir donner à la fente du spectroscope une ouverture un peu plus grande que celle dont je venais de faire usage pour l'examen des cornes; cette largeur était d'ailleurs assez faible pour montrer encore les principales raies noires de Fraunhofer.

Nine brilliant lines seen in spectrum of prominence.

Dés l'instant de l'obscurité totale, la fente du spectroscope ayant été portée sur l'image de la longue protubérance qui se montrait alors sur le bord oriental du soleil, je vis immédiatement une série de neuf lignes brillantes—très-brillantes même—se détachent sur un fond uniforme presque noir, ou plutôt d'un violacé très-obscur; aucune trace de spectre coloré donné par la couronne, et pouvant servir de point de repère pour la mesure de la deviation des lignes brillantes. Néanmoins, par leur disposition dans le champ, par leur espacement relatif, par leur couleur, et enfin par la physionomie même de leur ensemble, ces lignes m'ont semblé pouvoir être assimilées aux principales raies du spectre solaire, B, D, E, *b*, une ligne inconnue, F, et deux lignes du groupe G.

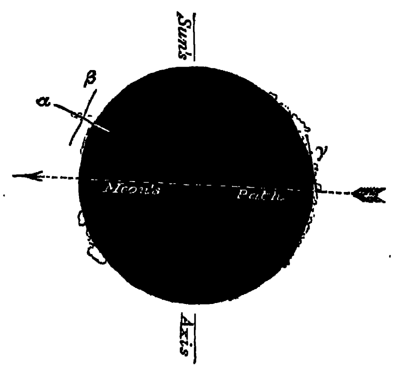


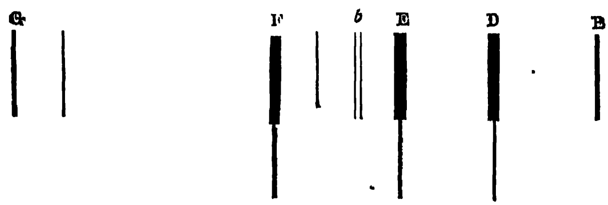
Diagram constructed to show the positions of the slit during Rayet's observations.

Le résultat prévu, celui que j'espérais vérifier à mon depart de France, se montrait avec une évidence parfaite. La lumière des protubérances analysée par le prisme donne une série de lignes brillantes; ces corps sont donc des amas, des jets d'une matière gazeuse incandescente, les flammes d'un phénomène chimique d'une puissance extrême, car la protubérance examinée avait environ trois minutes, soit à peu près 34,000 lieues de hauteur véritable.

Pendant les observations précédentes, la fente du spectroscope était parallèle à la grande longueur de la protubérance; aussi voyait-on dans l'appareil des lignes lumineuses d'une hauteur sensible, en relation directe avec la hauteur de l'image focale de la protubérance. La fente ayant alors été tournée de 90 degrés, les raies se sont trouvées réduites à des lignes très-courtes, presque des points, répondant à la faible largeur de la corne lumineuse considérée. Les lignes brillantes représentant donc bien le spectre de la lumière propre des protubérances, puisque leur longueur, change avec l'orientation de la fente.

La fente ayant été replacée dans sa première position, parallèle à la hauteur de la corne, je fis à la hâte un croquis grossier du phénomène; ce croquis est reproduit dans le dessin ci-joint, où je me suis efforcé de donner aux divers traits une épaisseur proportionnelle à l'intensité lumineuse des lignes qu'ils figurent.

Rayet's observation.



Sketch made at the time by Rayet.*

Les lignes les plus vives, les plus éclatantes, étaient: la ligne rouge B, la ligne jaune D, la ligne verte E, la ligne bleue F, et enfin la ligne violette, la plus réfrangible; les autres étaient beaucoup plus faibles, et surtout offraient une largeur beaucoup moindre.

Toutes les lignes se terminaient brusquement au pointe du champ qui répondait au bord de la lune, mais de l'autre côté, vers celui de l'image de l'atmosphère solaire, elles se prolongeaient d'une manière inégale.

These lines continued outwards into the area corresponding to the corona.

Les lignes très-vives, D, E, et F, se continuaient au delà de la longueur moyenne par un trait lumineux très faible qui leur donnait environ une hauteur double des voisines.

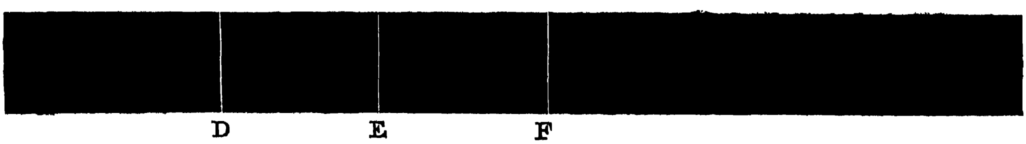


Diagram constructed to show the lines observed by Raye in the spectrum of the corona.

Une certaine portion des gaz incandescents qui forment les protubérances (ceux auxquels répondent les lignes D, E, F) se répand donc dans l'atmosphère solaire, au delà des limites que l'œil assigne en général à ces expansions.

L'examen de cette protubérance étant terminé, je mis la fente sur la region lumineuse qui était à l'occident du soleil. Le spectre était cette fois encore formé de lignes brillantes, disposées comme dans le premier cas; seulement je n'ai vu qu'une seule ligne violette, toutes les protubérances ne semblent donc point identiques.

* The above woodcut has been made from an illustration given in M. Stephan's report, p. 25.

Prof. Harkness.

41° 35′ 35″ N. } DES MOINES,
93° 39′ 5″ W. } 7th August, 1869.

"Washington Observations" for 1867, Appendix ii., pp. 25-96.

Instruments.—An achromatic telescope by Alvan Clark, 3·01 inches aperture and 43·58 inches focal length—equatorially mounted, but without clockwork. Finder with an adjustable needle-point showing place of slit. A single-prism spectroscope, with an illuminated scale to read the place of lines.

(p. 28.) The following are the constants relating to the spectroscope:

Small Telescope.

Focal distance of object glass . . .	6·55 inches.
Clear aperture of object glass . . .	0·86 inches.
Diameter of field of view . . .	5° 33′
Magnifying power	5·71 diameters.

Collimating lens for slit.

Focal distance	6·52 inches.
Clear aperture	0·82 inches.

Collimating lens for scale.

Focal distance	4·17 inches.
Clear aperture	0·82 inches.

Prism.

Refracting angle	60° 8′
Minimum deviation of line D . . .	47° 44′
Refractive index	1·613
Density	3·532

1. Slit parallel to the direction of the moon's path. The spectra of four prominences were observed, and the lines C, D, 1497, 1611, F, and 2770 were registered. The greatest number of lines were observed in the spectra of those prominences whose lower regions were most exposed.

2. In the spectrum of the corona the only line observed was registered as corresponding to K 1497.

(p. 60.) When the eclipse had so far progressed as to reduce the sun to a crescent, with the assistance of Professor T. H. SAFFORD, I adjusted the needle in the finder, so that when its point fell upon a horn of the crescent the image of that horn fell accurately within the jaws of the spectroscope slit. This, with some other little matters, occupied my time till within three minutes of the totality, when, according to previous arrangement, I called Professor EASTMAN, who was to assist me in making the spectroscope observations by placing and keeping the needle-point of the finder successively upon the different objects to be examined.

It seems to me that one of the *desiderata* in spectroscopic observations of the sun during total eclipses is to penetrate as low down towards the

photosphere as possible. In order to accomplish this, I placed the slit of my spectroscope parallel to the moon's path, and clamped it in that position, and so it remained during all my observations. **Harkness observation.**

Professor EASTMAN's eye was at the finder, and mine at the spectroscope, at least a minute before the commencement of totality, but he saw no prominences. Presently the sunlight disappeared like the snuffing out of a candle, and simultaneously a suppressed, but very audible, "Oh, oh!" arose from the spectators in the neighbourhood. Instantly he placed the needle-point on the prominence marked 1 in the figure, and I recorded its spectrum as rapidly as possible. Then we passed on to the prominences marked 2 and 3, and their spectra were successively recorded in like manner. Next I asked him to give me the corona, and he placed the needle-point at C^1. No spectrum appearing, I asked him to try another place, and he placed the needle at C^2. Still nothing was visible; and raising my head from the instrument for the first time since the commencement of totality, I remarked,

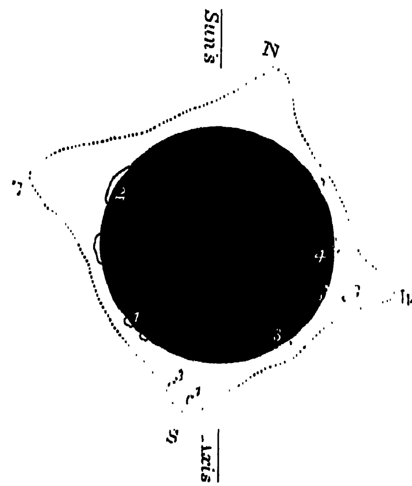


Diagram made by Eastman showing the place of the slit during Harkness' observations.*

"Can't see any spectrum; don't believe we will get any." "Oh yes, we will," said he. At that instant it struck me that perhaps the slit was too narrow, so I opened it a little, and then again placed my eye at

Diagram to illustrate the spectrum of the corona observed by Harkness.

the instrument. In the meantime he had put the needle-point on a very bright part of the corona, marked C^3 in the figure, and I at once saw a continuous spectrum about as bright as that given by the full moon on a **Spectrum of corona.**

* The above diagram has been made from the woodcut given upon p. 60 of Prof. HARKNESS' report. It has been reduced to the scale of the other diagrams showing the positions of slit, and has been turned round so that the sun's axis is vertical upon the page. The orientation is taken from the north point as given by EASTMAN.

Harkness' observation.

clear night. Remembering that the observers in India, in August 1868, had said that the corona gives a continuous spectrum *with absorption lines*,* I looked very carefully for them, but to my great surprise I could see none, and I am perfectly satisfied that none were visible in my instrument; on the contrary, I saw an absolutely continuous spectrum, crossed by a single bright line, whose position was recorded.

Once more raising my head from the instrument, I glanced upwards to the sky, and saw the moon encircled by the corona, and accompanied by one remarkably large prominence, which was attached to the lower limb of the sun. I was well aware that the red prominences are sometimes visible to the naked eye, but this one was so exceedingly conspicuous that it could not fail to attract the attention of the most careless observer. Almost without thinking what I was doing, I asked Professor EASTMAN to point the spectroscope to it. He replied, "You have had it already." "Never mind; give it to me again," said I. He did so, and, as it is the prominence marked 3 in the figure, I have recorded its spectrum in the column headed 3^2 in the table below. Professor EASTMAN then looked down to the chronometer in order to take up its beat for the purpose of noting the end of the totality. As he did so, I glanced into the finder, so that I might get some idea of the appearance of a total eclipse as seen through a telescope of small power. My view of it may have lasted five or ten seconds, certainly not more, yet the magnificence of the spectacle is so indelibly impressed upon my memory that it will be years ere I forget it. When he looked up from the chronometer I replaced my eye at the spectroscope, and asked him to give me another prominence. He put the needle-point on the one marked 4 in the figure, and while I was yet engaged in recording its spectrum there came a sudden burst of light, and Professor EASTMAN withdrew his eye from the finder, exclaiming, "All over!" It was too true. The event, for the proper observation of which we had travelled so far, and spent so much time and thought and money, had come and gone; and now it remains for the scientific world to judge whether or not we made the most of our opportunity.

Professor Eastman's sketch.

Professor EASTMAN at once sat down and made a sketch of the corona and prominences as they appeared to him in the finder, numbering the prominences in the order in which he had given them to me in the

* It will be seen that this was a mistake on the part of Prof. HARKNESS.

spectroscope, and also marking the places on the corona at which he had pointed. I had recorded the spectrum observations myself, using for that purpose a small memorandum book, writing down the figures without looking at the page, and recording only one spectrum at each opening of the book—that is, when I had recorded one spectrum I always turned the leaf before recording another—thus devoting two whole pages to each observation. Such being the state of the case, all that was necessary in order to identify each spectrum with the prominence to which it belonged, was for me to mark the records of the spectra in my note-book with the same numbers as those employed by Professor EASTMAN on his sketch, and that I did at once; therefore I think no question can ever be raised as to the prominences to which the spectra belonged.

Harkness' observation.

At the time of making these observations, the impression left on my mind was that the spectra given by the different prominences differed from each other, not only in the number of the lines, but in their position also. It was not till four hours after the eclipse that I had time to compare them with each other; and when I did so, arranging them as in the table below, great was my surprise to find that the difference between the different prominences was *only in the number of lines*, and not in their position at all. Before passing to the consideration of the lines, however, it will be best to mention some particulars relative to the adjustments of the spectroscope, and the method pursued in making the observations.

Spectra of different prominences only differ as to the number of the lines.

Some minutes before the beginning of the totality the micrometer scale was so adjusted that its fiftieth division coincided exactly with the mean of the two sodium lines which together form the line D; and the slit was open to such a width as to give a fine, sharp definition of all the lines. The instrument remained in that condition till the observation of the spectrum of the corona, before which the slit was opened a little wider. After that, none of the adjustments were altered in the slightest until next day. Immediately after the end of totality the scale-reading of the line D was tested,—first by observing the position of the black line in the solar spectrum, and then by placing the flame of an alcohol lamp, whose wick contained a little common salt, before the object-glass of the telescope, and observing the position of the resulting bright line. In both cases the reading was exactly fifty divisions, thus proving that the instrument had kept its adjustment during the observations of the prominences and corona.

Adjustment of micrometer scale.

Harkness' observation.

Then the following readings of the positions of some of the lines of the solar spectrum were taken:—

C, 36·2	E, 67·9	F, 84·8	116·0
D, 50·0	*b*, 71·5	115·0	G, 117·8

After that the spectroscope was detached from the telescope. Next morning, before any of the adjustments had been altered in the slightest, a sodium flame was put before the slit of the spectroscope, and the width of the resulting bright line was observed to be 0·8 of a scale division.

Width of slit.

From the angular value of one division of the scale together with the focal length of the collimating lens of the slit, it can easily be shown that when the width of the bright sodium line is one division, the width of the slit is 0·0037 of an inch. Therefore, at and after the observation of the spectrum of the corona, the width of the opening of the slit was 0·0030 of an inch; in observing the spectra of the prominence before that, it was a little narrower. As my instrument gives a spectrum about 330′ in length, the whole of which is visible at once in the field of view of its telescope, it is admirably adapted for rapid work. But when the telescope is adjusted to give the best possible definition of the lines near D, those near H, although still quite distinct, are nevertheless slightly out of focus, and by moving the eye across the eyepiece their scale-reading can be made to vary a little.

To have adjusted the focus accurately on each line observed during the eclipse would have involved an expenditure of time not for one moment to be thought of, and, as each scale-division corresponds to somewhat less than 2′, I therefore judged it best to observe as many spectra as possible, noting the position of each bright line to the nearest half of a scale-division only, and trusting that, from the closely approximate positions thus obtained, all the lines might be found at any time after the eclipse with a sufficiently powerful instrument. Now let us pass to the consideration of the observations.* They are given in the table below, the first column of which contains the letters of such of the lines as are so designated; the columns headed 1, 2, 3^1, 3^2, and 4, contain respectively the spectra of the prominences marked 1, 2, 3 and 4 in the diagram, the column headed 3^1 con-

Comparison of observations.

* A coloured diagram showing the spectra of the different prominences observed is given as Plate V. of the "Washington Observations" for 1867, Appendix II. A woodcut of Prof. Harkness' spectroscope is given as Plate IV.

taining the record of the first, and that headed 3^2 the record of the second spectrum observed from the prominence 3; the column headed "corona" contains the reading of the bright line in the spectrum of the corona. Harkness' observation.

	1	2	3^1	Corona.	3^2	4	Mean.	Kirch. Scale.	Wave ength.
C	46·0	37·0	36·5	...	36·0	36·0	36·3	693	656·9
D	50·0	50·5	...	...	50·0	50·0	50·1	1007	589·4
	67·5	67·0	67·0	66·5	66·5	67·5	67·0	1497	530·0
	...	...	...	...	70·5	...	70·5	1611	520·1
F	85·0	...	...	...	84·0	84·5	84·5	2069	487·5
	...	...	...	...	114·0	114·5	114·2	2770	435·9

The number 46, recorded on line C in column 1, is evidently a misreading of ten divisions. It should doubtless have been 36. Making this correction, and bearing in mind that the readings were made at a glance, to the nearest half division only, without stopping to verify them, I think it will be admitted that all the numbers on any one horizontal line of the table are sufficiently near to each other to warrant me in assuming them to be readings of one and the same bright line. In other words, during the whole of the totality I only observed six lines; the double line D being counted as a single line because it so appeared to me. I have therefore taken the mean of the numbers on each horizontal line, and placed them in the column headed "mean." These I consider to be the observed scale-readings of the bright lines; and in the columns headed "Kirch. scale," and "wave length," I have given the corresponding readings of Kirchhoff's scale, and the wave lengths expressed in millionths of a millimeter.

Now let us examine the position of each prominence at the time its spectrum was taken. The spectrum of 1 was observed as soon after the beginning of the totality as possible; but a glance at the figure shows that it lay very far from the path of the moon's centre, and therefore its base was not visible. It gave four bright lines. 2 was next examined. It lay almost exactly in the path of the moon's centre, but by this time she had advanced so far that probably it was not visible more than half way down to its base. It gave three bright lines. Then the telescope was pointed at 3, which being on the south-western limb of the sun, and distant from the path of Most lines seen in the spectra of prominences whose lower regions were exposed.

Harkness' observation.

the moon's centre, had only just begun to be much uncovered. Its summit was all that was visible, and it gave but two bright lines. After spending some time on the corona, 3 was again examined. As the moon had moved forward considerably, the prominence was uncovered much farther down towards the sun, and now it gave no less than six bright lines. Finally 4 was pointed at, and as it lay almost exactly in the path of the moon's centre, and the totality ended while it was yet under examination, the spectroscope must have penetrated down to its very base. I recorded five bright lines from it, but I am not certain there were no more, because I had not done with it when I was stopped by the flood of returning sunlight. The first thing that would be likely to strike a person on looking at the observations is that no two prominences give the same spectrum; but I think it is now evident that this does not indicate any difference of constitution among them. On the contrary, the number of lines visible seems to depend solely on the *part* of the prominence examined. If we take the spectrum from near the summit we get but few lines; if we take it lower down, we get more lines, but those we found at the top are still there; if we take it near the base, all the lines we had before remain, and, in addition, some new ones appear.

Prof. E. C. Pickering. 40° 57′ N. 91° 38′ W. } MT. PLEASANT, IOWA, AMERICA, 9th Aug., 1869,

"The Journal of the Franklin Institute," Vol. lxxxviii., p. 285.

Instrument—An integrating spectroscope, with one prism of 60°. Angle of integration, 7°.

Continuous spectrum sufficiently bright to have its upper and lower edges well defined. Two or three bright lines—brightest near E, next near C.

A chemical spectroscope, with one 60° prism was loaned me by Prof. Van Vleck, and was tied to the back of a chair by a piece of cloth, just tightly enough to make it remain in whatever position it was placed. As no lens was placed in front of it, all the light which fell on the slit from a circle about 7° in diameter passed through the instrument. Turning it towards the sun before totality, the latter remained in the field. This is probably the best way to obtain the spectrum of the corona, as there is very little loss of light; the protuberances, however, are so small that their spectra would be faint—although the advantage of not having to move the instrument is a great one. The spectrum appeared to be continuous

with two or three bright lines—the brightest in the neighbourhood of E, and the next near C; but as no dark solar lines were visible, these positions

Diagram to illustrate the spectrum observed by Pickering.

cannot be relied upon. The absence of the dark lines may be due to the want of brilliancy of the spectrum, although this was bright enough to leave its upper and lower edges well defined.

Professor C. A. Young.	40° 48′ 17″ N. 91° 4′ 0″ W.	BURLINGTON, IOWA, 9th Aug., 1869.

"The American Journal of Science and Arts" for November, 1869, Vol. xlviii., No. 144, pp. 370-78.

Instrument.—A telescope of 4 inches aperture and 30 inches focal length, with Huyghenian eyepiece, enlarging the image of the sun to $2\frac{1}{8}$ inches in diameter. Slit one-eighth of an inch long. Spectroscope of 5 prisms of 45° each, with telescopes of $2\frac{1}{4}$ inches aperture and $16\frac{1}{2}$ inches focal length.

(p. 371.) The spectroscopic combination employed was compiled for the occasion from various instruments belonging to Dartmouth College.

The telescope which formed the solar image was a comet-seeker, by Merz and Son, of four inches aperture, and 30 inches focal length. An ordinary Huyghenian eyepiece enlarged the image, so that when it fell upon the slit of the spectroscope, at a distance of 5 inches, it was $2\frac{1}{8}$ inches in diameter. The use of an eyepiece gave an easy means for securing the accurate focus of the limb at the slit,—an adjustment of great importance. The spectroscope proper had telescopes of $2\frac{1}{4}$ inches aperture, and $16\frac{1}{2}$ inches focal length (by Alvan Clark). The eye-telescope was provided with an eyepiece, magnifying 18 times, and a wire micrometer, constructed from a reading microscope, for determining the position of any new lines in the spectrum by referring them to those already known. This, although a very accurate method, was too slow to be well adapted to eclipse-observations, but was the only arrangement I could construct with the time and means at my command.

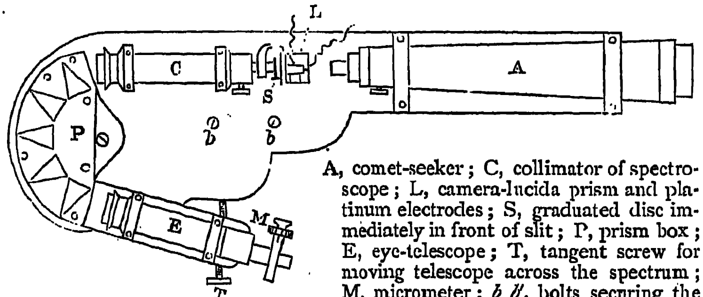
Slit $\frac{1}{8}$th of an in., or about $3\frac{1}{2}'$ long. At the beginning of totality it was set radial at + 140° from N. point. Lines seen, C, 1017·5, 1250 ± 20, 1350 ± 20, and 1474, extending all across the field. The slit was then shifted to a prominence on the opposite side of the sun, when the violet end of the spectrum was examined; the lines noted were F, 2602, 2796, and *h*. There was a faint continuous spectrum, without any trace of dark lines. The position of 2602 ± 2 was determined micrometrically but the positions of 1250 and 1350 were merely estimated. 1474 was seen to be the reversal of the solar absorption line.

The collimator had a slit of one-eighth of an inch long, and of adjustable width. It was provided with a small prism, which could be turned up so as to throw into half the slit light from an electric spark formed between platinum electrodes, by a small induction coil and Leyden jar.

It also carried a thin brass disc about 2½ inches in diameter, placed in front of the slit, with a hole of one-eighth of an inch in the centre. This disc was covered with white paper and graduated into sectors of 10°, by lines radiating from the centre. This graduated screen, upon which the image of the sun was clearly visible, even during the totality, answered the purpose of a finder; and its graduation furnished the means of determining within less than 3° the position of any object observed on the sun's limb, or of bringing any desired portion of the limb to the slit.

The spectrum was formed by a train of five prisms of 45° each, with faces 2¼ by 3¼ inches. They gave a dispersion of about 18° between A and H, with a total deviation of about 165° for the D line. The box which contained them was so connected by a link with the arm which carried the eye-telescope, that whenever the latter was moved by its tangent screw along the spectrum, the prism box would turn through an angle just half as great. Thus the prisms were kept in the position of best definition for whatever lines were in the middle of the field of view; the extent of which was sufficient to embrace D and E together.

The telescope and spectroscope proper were firmly secured to a wooden framework, and this was mounted equatorially with slow-motion screws, in both right ascension and declination. The figure gives an idea of the appearance of the whole.



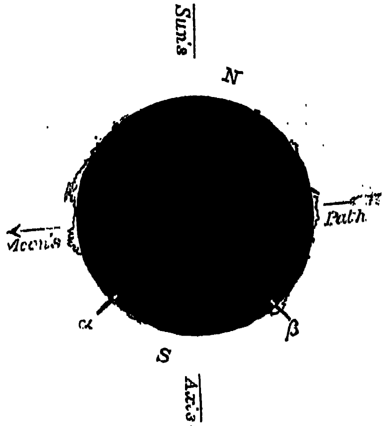
A, comet-seeker; C, collimator of spectroscope; L, camera-lucida prism and platinum electrodes; S, graduated disc immediately in front of slit; P, prism box; E, eye-telescope; T, tangent screw for moving telescope across the spectrum; M, micrometer; *b b'*, bolts securing the framework to the equatorial mounting.

The spectrum was about 1¾ inches broad (referred to a distance of 10 inches), and about 45 long. It showed all the lines of Kirchhoff's maps of the spectrum; such lines as the nickel line between D_1 and D_2 being perfectly distinct.

(p. 375.) Before the eclipse began, the existence of prominences on the limb of the sun had been ascertained in the following positions (reckoning from the north point through the east): a large but faint one near +90°; a small but bright one at +146° (the photographs show two here); a long low one at −70°, very near the point of first contact; and an enormous and very bright one at −130°; with several others of small elevation, but considerable length, on different parts of the limb. Young's observation.

Observation.

At the beginning of totality the slit was upon the prominences at + 160°, the eye-telescope upon C. As soon as totality commenced, this line blazed out magnificently; but, from the small extent of the prominence, did not reach across the spectrum. No line appeared below C, nor any between C and D. The orange line, which for convenience I will call D_3 (1017·5 K), was beautifully bright, but no longer than C. Between it and the next prominent line were two faint lines, situated by estimation at 1250 ± 20 and 1350 ± 20 of Kirchhoff's scale. Then came the 1474 K line, which was very bright, though by no means equal to C and D_3; but attention was immediately arrested by the fact that, unlike them, it extended clear across the spectrum, and on moving the slit away from the protuberance it persisted, while D_3, visible in the edge of the field, disappeared. Thus it was evident that† *this line belonged, not to the spectrum of the protuberance, but to that of the corona.* 1474 seen extending all across the field.



α Position of slit at first observation.
β Ditto at second observation.*

My impression—but I do not feel at all sure of it—is that the two faint lines between it and D_3 behaved in the same manner, and are also corona lines.‡

* Drawings from which the above woodcut and the diagram illustrating the spectrum observed, have been made, were submitted to Prof. YOUNG, and approved of by him.

† *(Note by Prof. Young.)*—On two or three occasions previously I had been very much surprised at not being able to detect this line in the spectrum of unusually bright prominences. On the other hand, I had once found it very easy to see at a place on the sun's limb where the other chromosphere lines, usually far more brilliant, were almost invisible.

‡ *(Note by Prof. Young.)*—A careful examination of the photographs, especially No. 2 of the Burlington totality pictures, somewhat diminishes my confidence in the conclusion of the

Young's observation.

I may as well confess that my uncertain memory here is due to the fact that just at this time, while my assistant was handing me the lantern with which to read the micrometer head, I looked over my shoulder for an instant, and beheld the most beautiful and impressive spectacle upon which my eyes have ever rested. It could not have been for five seconds, but the effect was so overwhelming as to drive away all certain recollection of what I had just seen. What I have recorded I recall from my notes taken down by my assistant.

Slit shifted.

By this time the moon had advanced so far that it became necessary to shift the slit to the great prominence on the opposite side of the sun. While my assistant was doing this I suppose I must, in the excitement of the moment, have run my eye over the region of the magnesium lines (*b*), and thrown them out of the field before he had brought anything upon the slit. At any rate, I saw nothing of these lines, which were evident enough to several other observers, and can think of no other way to account for their having escaped me.

The F line in the spectrum of the great protuberance was absolutely glorious,—broad at the base, and tapering upward *crookedly*, as Lockyer has before often observed.

Next appeared a new line,* about as bright as 1474, at 2602 $\pm$ 2 of Kirchhoff's scale. Its position was carefully determined by micrometrical reference to the next line, 2796 K (hydrogen γ), which was very bright:

text as to the nature of these three lines (1250, 1350, and 1474). They certainly do not belong to the spectrum of the *most brilliant* portion of the prominences; but around the prominences of the eastern limb, on which the slit of the spectroscope was directed during the first half of totality, the photograph shows a pretty extensive and well-defined nebulosity, evidently distinct from, though associated with, the brilliant nuclei. Now, it is *possible* that these lines may belong to this nebulosity, and not to the corona proper; for I cannot recall with certainty whether 1474 retained its brilliance at any considerable distance from the prominences, or only in their immediate neighbourhood. My strong impression, however, is that the former was the case, and that the text is correct. I am confirmed in this opinion by Prof. PICKERING's observation. He used a single-prism spectroscope, with the slit of the collimator simply directed to the sun, and having no lens in front of it. With this arrangement he saw only three or four bright lines,—*the brightest near* E (1474). Now, this is exactly what ought to occur, if that line really belongs to the corona, which, from its great extent, furnished to his instrument a far greater quantity of light than the prominences.

* *(Note by Prof. Young.)*—This is undoubtedly the line described by Lieut. HERSCHEL as between F and G.

h was also seen, very clear, but hardly brilliant. In all, I saw nine bright lines. Young's observation.

A faint continuous spectrum, without any traces of dark lines in it, was also visible, evidently due to the corona. . . . .

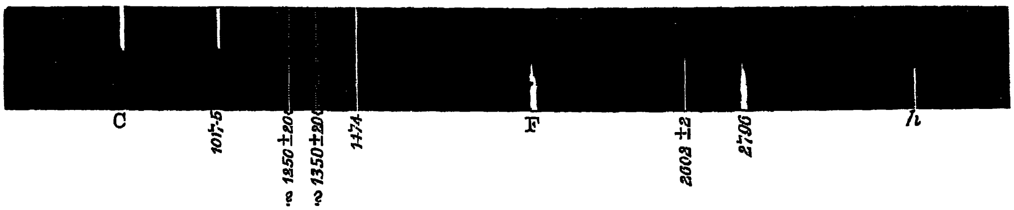


Diagram constructed to illustrate the spectrum observed by Young.

The figure exhibits the position of the lines seen by me.

My observations decide nothing as to specific difference between the different protuberances, since, from the smallness of my field of view, I was obliged to observe a portion of the spectrum on one of the prominences, and the rest on another. I had just completed the measurement of 2602 * when the totality ended. This line disappeared instantly; but 2796 was nearly a minute in resuming its usual faintness. . . . .

The green coronal line seen to be the reversal of the Fraunhofer line 1474.

(p. 377.) The positions of the faint lines (K 1250 and 1350) being only estimations, very little weight can of course be given them. But as to the position of 1474 in the corona spectrum, there cannot be the least doubt. It is the reversal of a well-marked, though not prominent line, just below E, put down as *iron* by both Kirchhoff and Angström, though not given by Huggins.

Professor Charles S. Pierce.

37° 50′ N. } BARDSTOWN, KENTUCKY,
85° 23′ W. } 7th August, 1869.

United States Coast Survey, Appendix No. 8 to Report for 1869, pp. 13, 14.

Instrument—A four-inch telescope mounted equatorially, but without clockwork; spectroscope consisting of a single flint-glass prism

* In the "Journal of the Franklin Institute" for Dec. 1869, at p. 420, Professor YOUNG gives an account of his observation of a prominence line unmistakably at K 2581·5; and he adds, "This observation has led me to doubt whether the line given in my Eclipse Report at K 2602 is rightly placed. A correction of one revolution of the micrometer screw, by means of which its position was referred to 2796, would give 2582·5 for its true position; and I might easily have committed such an error in the excitement and haste of the moment."

and a three-prism direct-vision spectroscope in place of its telescope.

Field of spectroscope extending from the red end of the spectrum to half-way between F and G. Slit upon great prominence. Five lines seen: F, *b* (dimmer line one-fourth the distance from *b* to D), line near D, and C. Spectrum of the corona not observed.

I was furnished with an elegant equatorial telescope, of four inches clear aperture and five feet focal length. Upon opposite sides of the tube of this telescope, and parallel to it, were attached two brass rods at the eye-end of the tube, and reaching about a foot beyond it. Upon these rods was fixed the spectroscope, and in such a manner that the slit was plainly visible. . . . . Pieces of white paper were pasted upon the brass-work of the slit to receive the image of the sun, which during totality could not well have been seen upon the polished brass. There was some danger of detaching this paper in opening and closing the slit, and I therefore wished to change the width of the slit as few times as possible during totality.

The spectroscope attached to my telescope contained a single flint-glass prism and a three-prism direct-vision spectroscope screwed in in place of its telescope. There were no means of measuring the positions of the lines. In order to bring different parts of the spectrum into view it was necessary to unscrew a binding-screw, which left the somewhat heavy arm that carried the direct-vision spectroscope entirely loose, and then to move this arm with the hand and tighten up the screw. When this was done the arm would fall a little, and it was only by looking at the spectrum and estimating how much the arm would fall that it was possible to set upon any part of the spectrum. During totality there might be no light in the field if the observer were to move away from a protuberance, and therefore no means of knowing to what part of the spectrum, if any, the arm was set. If the slit was opened to give full light, the paper pasted on it might become detached, and render it impossible to set the slit on a protuberance. There was no clockwork on the telescope, and the observers were in continual apprehension of some disturbance in the crowd of mostly ignorant spectators; therefore an attempt to move this arm was a thing to be dreaded. On the other hand, it could be so set as to afford a view of the spectrum from its red extremity up to half-way between F and G. Under the circumstances, I would not venture to move it. If I had been alone, and consequently at my ease, I should have done so.

My telescope was pointed for me by Mr. N. S. SCHALER, the geologist, who generously relinquished his opportunity of witnessing the sublime phenomenon undisturbed, and offered his assistance in the astronomical observations. My telescope was, therefore, managed for me with perfect skill and coolness. **Pierce's observation.**

Upon the morning of the 6th I set up my instrument and searched for the protuberances. I found only one, which was upon the following side of the sun, and was very yellow—that is to say, the yellow line near D was relatively very bright in it. Indeed, I could not see the F line at all. On the morning of the 7th I examined the sun with greater care, and noticed several protuberances (which were afterwards plainly seen at totality), but none of these were as brilliant as the one that had been seen the day before continued to be; and this was now less high, extended over a larger arc on the disc of the sun, and was still more yellow than it had previously appeared.

At the instant of totality my telescope was pointed on this protuberance, and my slit was rather narrow. At that instant the continuous **Observation.**

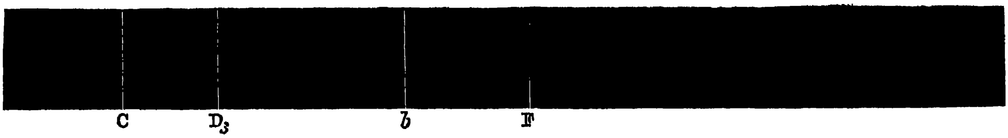


Diagram to illustrate the prominence spectrum observed by Pierce.

spectrum vanished, and five lines brilliantly coloured became visible. These were F, *b*, another dimmer and broader line, say one-fourth of the distance from *b* to D, the well-known yellow line near D, and C.

After observing the spectrum of this protuberance at different positions, I looked at the sun, and was pleased to find my conception of the shape and colour of this protuberance entirely confirmed. The same glance showed me, upon the south-western limb of the sun (where my business chiefly lay) a well-marked rose-coloured protuberance. I first observed the spectrum of another red protuberance on the southern edge, and then that of the one just mentioned. I found spectra of the red protuberances to be alike; they differed from that of the yellow one only in the relative greater brilliancy of the red, yellow, and blue lines in the former, the fainter green being especially much fainter. I had no doubt, from my previous observations, that the yellow line was also

Pierce's observation.

less bright in the red protuberances, but it appeared so bright that I could not perceive that it was less bright than in the yellow protuberance.

Mr. Shaler then pointed for me on the corona, and I was just opening the slit to get more light when the sun burst forth and put an end to my observations. Two seconds more, or a little more privacy, would have enabled me to get it.

Professor J. Lawrence Smith.

37° 50′ N. } Bardstown, Kentucky,
85° 23′ W. } 7th August, 1869.

"United States Coast Survey," Appendix No. 8 to Report for 1869, p. 15.

Instrument—An integrating spectroscope.

Four bright lines seen: C or near C, D or near D, one in the green, and F or near F.

The most interesting part of my observations is, that a good single-prism spectroscope will give at least four bright lines in the protuberances, unaided by a telescope to form a disc of the sun. The spectroscope attached to the telescope gave Mr. Pierce five lines; but I do not think that I speak too confidently in stating that five lines might have been seen by the naked spectroscope had it been mounted for giving direction to it.

Diagram to illustrate the spectrum observed by Lawrence Smith.

The four bright lines, as nearly as I could make them out, were one in the red, in or near the line C; one in the orange, in or near D; one in the green; and one in the blue, in or near F.

Professor Joseph Winlock.

38° 12′ 45·36″ N. } Shelbyville,
85° 13′ 22″ W. } 7th August, 1869.

"United States Coast Survey Report for 1869," Appendix No. 8, p. 12.

Instrument—For spectroscopic observations, an excellent equatorial by Merz, of 9½ feet focal length and 7½ inches aperture, was employed, to which was attached a spectroscope of two flint-glass prisms, made by Troughton and Simms.

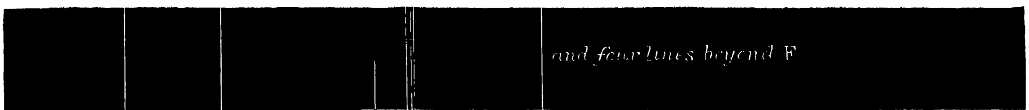
Corona: faint continuous spectrum; no lines seen. Prominence spectrum: C, D, F (a short line at or very near E), the three lines of *b*, and four lines above F

The chromosphere was carefully examined both before and after the eclipse. Only three lines could be seen: C, one near D, and F. During totality only the brightest protuberance on the lower limb of the sun was examined carefully. In the short time occupied in getting this, nothing

Diagram to illustrate the spectrum of the corona observed by Winlock.

was seen but a faint continuous spectrum; but since the telescope took in only a small part of the spectrum at once, nothing conclusive can be inferred from the observation as to the non-existence of bright lines in the corona.

During totality, eleven bright lines were seen. Besides the three already specified, there was a short line at or very near E. The three lines of *b* were bright and very sharp, and there were four lines above F.



Although these lines were very dark on a bright * ground, all of them but the three seen before the eclipse disappeared instantly on the first burst of sunlight, and the same point in the sun's disc was examined with great care after totality without finding any of the lines except those above described.

Mr. C. Carpmael.

36° 25′ N. } ESTEPONA, SPAIN,
5° 8′ W. } 22nd December, 1870.

MS. Reports of the 1870 Expedition.

Instrument—Equatorial refracting telescope without clock motion, $5\frac{1}{4}$ in. aperture, 6 ft. 4 in. focal length; spectroscope, with $1\frac{1}{4}$ in. equi-

* Query "very bright on a dark ground." It may seem at first sight strange that the line near E should be spoken of as a "short line," but if the light-grasping power of the spectroscopic combination used was not sufficient to show the green line of the corona, the observation would only indicate that the incandescent 1474 matter was not projected to the same altitude in the prominence as the incandescent hydrogen, magnesium, and D_3 matter.

lateral prism, and a graduated scale reading to minutes; magnifying power of five; focal length of collimator 13 inches; length of slit subtending about 30′ of arc.

Slit set tangential at a distance of some 3′ from the east limb. Three bright lines were observed: the centre one (which extended entirely across the field, but was fainter towards the extremities), was found by measurement to correspond to K. 1359.

The instrument was so adjusted that the "*b*" focus of the object-glass fell upon the slit; the eyepiece also was focussed for the "*b*" line, which was left nearly in the centre of the field of view.

The adjustments were made some time before totality, and as rain came on the instrument was capped. The rain continued until after the totality had commenced, but a small break in the clouds enabled me to obtain a glimpse of some seconds' duration of the corona.

As the corona became visible, the instrument was laid upon it, and then kept in position by Mr. Gordon, who guided it by means of the finder.

At first no spectrum was seen, so I asked Mr. Gordon to open the slit (which had previously been set so that the principal solar lines were just defined when the instrument was directed upon a heavy cloud).

As the slit was being opened, three bright lines sprang into view, which before there was time to speak widened as the slit was still further opened.

I had a comparison spectrum at the top of the field, the discharge being from iron points through air; but the iron lines not coming out satisfactorily, I changed the comparison spectrum to one from a magnesium point in hydrogen. Mr. Gordon had the means of doing this with great rapidity.

Middle corona line bisected.

Meanwhile I endeavoured to intersect with the cross-wires the middle corona line (by which I mean the line which I saw whilst the instrument was directed to the corona); to this line almost exclusively I directed my attention, only noticing that the other two lines were towards the extremities of the field of view, and not equally distant from the middle line, although which was the more distant I cannot recall with certainty. Clouds came over before I had brought the cross-wires exactly to the centre of the band.

As soon as, or I believe an instant before, I lost sight of the object, I marked the divided brass circle with a needle-point, so as to be able to replace the telescope at any time to the position it then occupied. I still kept my eye to the telescope, though seeing nothing, until light reappeared; and then, being uncertain whether the first mark on the metal was sufficiently distinct, I made a second deep mark.

On subsequent examination, I found that the telescope had shifted

before the second mark was made, but I do not think that there is the slightest uncertainty in my results from this cause, the nature of the second line enabling me clearly to distinguish it from the first; besides which, this second mark is far away from the position which I judged by means of the comparison spectrum, and is near the F line. . . . . Carpmael's observation.

By a very hasty comparison I estimated the central corona line to be so situated between *b* and C that its distance from C was three times its distance from *b*.

Both before and after the eclipse I read the positions in my instrument of some of the principal solar lines; they are as follows:—

	Readings before Eclipse.	After Eclipse.
C	49° 32′	49° 33′
D	50° 15′	50° 14′
Double line of *b*	51° 17′	51° 17′
F	52° 0½′	52° 0′

The first line which I marked reads 50° 54′. I have since determined the correction in the position of the line which has to be made in consequence of the broad slit which I used. My slit was found to be open as far as it would go, or slightly less than ·045 in. . . . . .

By interpolation I find that the reading on Kirchhoff's scale, corresponding with my corrected reading of 50° 50′, is about 1359. . . . . .

My slit whilst observing was, Mr. Gordon informs me, tangential to the sun. This he was able to judge because the wires of the finder had previously been set so that whilst the sun's course was along the horizontal wire, the vertical wire was parallel to the slit.

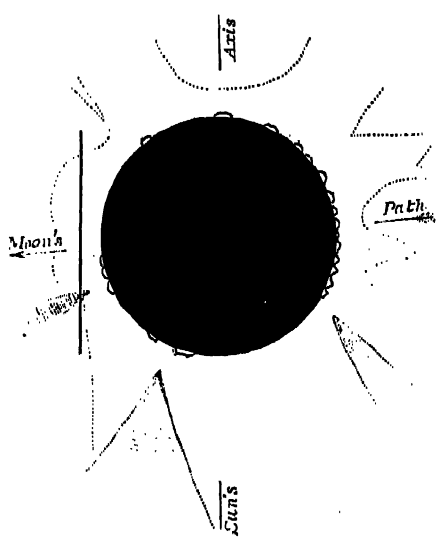


Diagram constructed to show the position of the slit during Carpmael's observation.

Mr. Gordon also tells me that he endeavoured to keep the vertical wire just clear of the moon's limb,* and also of the solar flames.

* If the centre of the slit was 3′ from the limb, the extremities of the slit would be more

Carpmael's observation.

The bright corona line extended entirely across the field of view, but was fainter towards the extremities. It is true that the comparison spectrum occupied the upper portion of the field; but when the brightest portion of the line was in the centre of the field, I could see it extending to

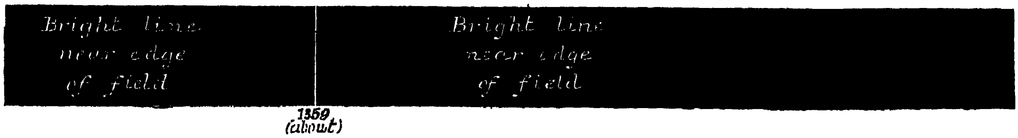


Diagram to illustrate the spectrum of the corona observed by Carpmael.

the extremity in one direction, and could judge that it extended equally in the other. This would make the distance from the sun at which the line remained visible one-third of the sun's radius at least.

Mr. Gordon.

36° 25′ N. } ESTEPONA, SPAIN,
5° 8′ W. } 22nd December, 1870.

MS. Reports of the 1870 Expedition.

Much cloud;—position of Mr. Carpmael's slit tangential, and about 6′ off the centre of the apparent right-hand limb.

I acted as assistant to Mr. CARPMAEL, who used a spectroscope. I was at the finder, and steered the telescope, which had neither clamp nor slow motion.

It was raining when totality commenced, and all our glasses were capped to prevent them being dimmed by moisture.

Suddenly we saw a patch of blue sky travelling along; some one called out, "It will be visible directly." We rushed to our places. I removed the caps and set the coil going. Just as I got to the finder, the eclipsed sun appeared through the gap in the clouds.

For a moment—not more than one or two seconds at the most—I could not get the sun into the finder. Mr. CARPMAEL looked along the outside of the tube of the large telescope, and threw it into the finder.

I then placed the cross-wires on a point distant from the limb about half the height of the corona (which I estimated to be about 6′ high), and "off" the centre of the apparent right-hand limb.

Then Mr. CARPMAEL called me to open the slit. I did so, and then

than 8′ from the limb. A diagram from which the woodcut showing the place of the slit has been made was submitted to Mr. CARPMAEL and approved of. The outline of the rifts and corona is taken from the Syracuse photograph.

substituted a hydrogen tube for the spark between iron poles in air, with which we had commenced.

Soon after this a cloud obscured the disc, and in a second or two more totality ended. I estimated the time during which totality was visible at about twelve seconds.

Lieut. Alex. B. Brown.

36° 38′ N. } MARIA LOUISA OBSERVATORY,
6° 12′ W. } 22nd December, 1870.

"Monthly Notices," xxxi., pp. 52-55.

Instrument—A 6-inch equatorial of 7 feet focus, moved by clockwork, and star-spectroscope fitted with a single equilateral prism of very dense glass.

Several parts of the corona were examined, but no bright lines were seen. A continuous spectrum without dark lines was all that was observed.

(p. 55.) I immediately directed my assistant to place the cross-wires of the finder on a portion of the corona about 8′ or 9′ from the obscured disc of the sun, when I at once got a *continuous spectrum* about equal in intensity

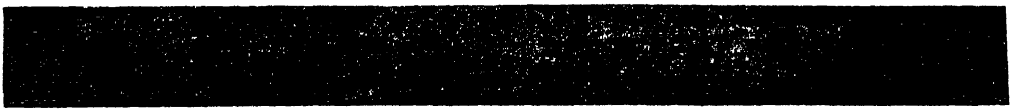


Diagram to illustrate the spectrum of the corona observed by A. B. Brown.

to that given by the moon just before entering its third quarter,* free from any lines, bright or dark. I then tried to shut off the light *partially* by decreasing my aperture; my spectrum faded, still I got no lines. I opened it more than before: no appreciable alteration in the colour or brightness of my spectrum, but still no lines. I then worked with the slit at its original aperture, and directed my assistant to take some other places on the corona between 4½′ and 25′ (about the top of the corona) from the sun's disc—which positions are marked in the sketch as black dots: the same result, a continuous spectrum free from lines. I searched in vain for the line 1474, and others whose positions I had before carefully determined; and, thanks to the kindness of Professor YOUNG, I had particularly noted the celebrated American line in his high dispersive spectroscope a few days before at Xerez. My spectroscope gave no indication of any bright lines on that luminous portion that I believe to be the true corona, and which formed an irregular curve round the bright portion

* See note respecting Lieut. BROWN's estimate of the brightness of the continuous spectrum of the corona on pp. 350—351.

A. B. Brown's observation.

surrounding the chromosphere (as seen by sketch). This might be due to the fact of there being none to notice, or that the unfavourable atmospheric conditions did not enable me to detect any with my comparatively low dispersive instrument. The parts of the corona I examined were from $4\frac{1}{2}'$ to $25'$ from the moon's disc—the actual positions being about $4\frac{1}{2}'$, $7'$, $12'$, $20'$, and $25'$ from the moon.

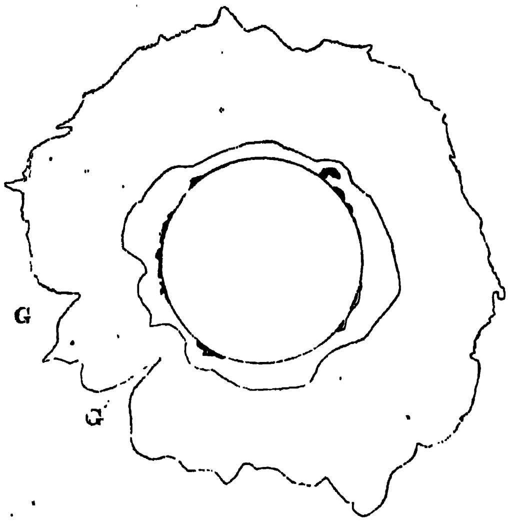


Diagram * showing the place of the slit during A. B. Brown's observations.

[After an examination of the spectrum of the prominences, Lieut. BROWN returned again to the corona.] He says:—

(p. 58.) I devoted the rest of the time to a further examination of the corona, with the same result as before. I also directed my cross-wires to be placed on the gap (marked G in the figure), and then the spectrum gave no lines, but almost entirely faded away; even upon further opening the slit, the green and blue portions seemed to be comparatively brighter with respect to the red end than before.

Commander Maclear.

36° 37′ 14″ N. 6° 11′ 13″ W. } SAN ANTONIO, NEAR PUERTO DE STA. MARIA, SPAIN, 22nd December, 1870.

MS. Reports of the 1870 Expedition.

Instrument.—A four-inch refractor, mounted equatorially, and five-prism direct-vision spectroscope, slit subtending about $10'$.

Slit set radially to east limb. At the beginning of totality, the solar spectrum vanished, leaving faint diffused light with bright lines near C, D, *b*, and F all across the spectrum.

The slit was so far open that the dark lines of the solar spectrum were very distinctly and well defined. It was not altered during the observations, and was afterwards estimated at $\frac{8}{100}$ of a millimeter. It was kept the whole time in a plane of declination radial to the moon's limb.

Just before totality I placed the slit about the middle of the thin

* The above diagram is the same as that given in the "Monthly Notices."

crescent of light and radial to it; kept it there by R.A. movement, and watched closely.

The slit was then moved to 8′ from the limb, and the same lines observed—then to the centre of the moon, still the same lines—at 8′ from the following limb C, D, E, *b*, F observed—then to the other limb, the lines near C D and F seen together with two new green and one blue line extending all across the spectrum. As the limb brightened, the lines between D and the blue line diminished one-quarter of their length from the left side.

As the last of the light disappeared, the solar spectrum vanished, giving place to a faint diffused light; at the same time bright bands appeared the whole width of the spectrum, about C, D, *b*, F.

The positions about D and F I am pretty certain about, but the one near C may have been a little nearer D, and that near to *b* may have been near E. A few seconds were lost in trying to estimate their positions.

I observed no dark absorption bands.

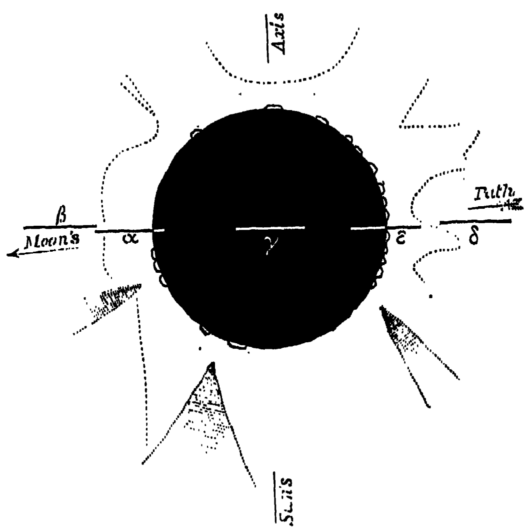


Diagram constructed to show the places of the slit during Maclear's observation.*

I then moved the telescope to what I estimated to be 8′ off the limb; the same lines were visible, and very bright. After a glance at the finder, to see if there were any streamers in the same plane of declination, I moved the slit to the centre of the moon's disc, and to my surprise found the same lines, but of only half the intensity. I looked at the finder to verify the position, and then moved the slit to about 8′ off the following limb of the moon, and recorded bright lines about C, D, E, *b*, F.

Bright lines seen at centre of moon's disc.

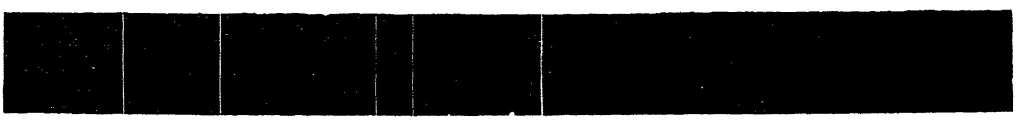


Diagram to illustrate the spectrum observed by Maclear.

I then moved in to the limb which was just beginning to brighten, bringing it about the middle of the slit, when two additional bright green lines, and one very bright blue, burst out the whole width of the slit.

At the same time I think one of the lines about E or *b* disappeared; but of this I am not sure, as my attention was taken by the new lines, and I had then so many bright lines in view.

* A diagram, from which the above woodcut has been made, was submitted to Capt. Maclear, and approved of by him. The outline of the rifts and corona is taken from the Syracuse photograph.

Maclear's observation.

As the limb brightened, the lines between D and the blue line diminished a quarter of their length, fading from the left side of the slit; then as the light broke in all disappeared, and were replaced by the ordinary solar spectrum.

Unfortunately, I did not at once verify the positions of the bright lines by comparison with Fraunhofer's lines,—I was so anxious to record immediately all my impressions.

I sat down at once and noted all that had occurred, then compared with what I had called out to the gentleman who had taken notes for me during the eclipse. The only difference I found was in the positions of the lines near E.

The places of the bright lines were obtained by their colours and their distances from D, in the spectroscope, which I had been constantly in the habit of using.

The two green lines which appeared on the following limb were near E, and the blue line appeared between F and G.

Positions of slit.

As to the position of the slit on the two limbs, I am quite certain, as I could see the limb in the slit both times. Of the position 8′ on either side, I am not so sure, as they were obtained by estimation of one-fourth the sun's diameter, and may have been more than 8′.

The position on the moon's disc was confirmed by reference to the finder, which I was quite satisfied with, at the commencement of the eclipse. I regret now that I did not sweep out till the lines faded, but at the time I was endeavouring to carry out faithfully a programme arranged beforehand.

Positions of bright lines observed:—

		Noted from memory.		Called out at time.
On 1st limb	=	C, D, E, F	=	C, D, *b*, F.
8′ off limb	=	same lines	=	same lines.
Centre of moon	=	same lines	=	C, D ($\frac{3}{4}$ between D and E; half-way between E and F).
8′ off following limb	=	same lines	=	C, D, E, *b*, F.
On limb		C, D. Full width of slit 3. Green bands shortened 1. Bright blue, full width	=	Not called out.

The Rev. S. J. Perry.

36° 37′ 13″ N. } SAN ANTONIO, SPAIN,
6° 11″ 13′ W. } 22nd December, 1870.

MS. Reports of the 1870 Expedition.

Instrument.—The telescope used was a Cassegrain of 8¾ inches clear aperture, mounted on a Tully altazimuth stand. The diameter of the direct image of the sun was 2⅞ inches, and the field of view 2$\frac{3}{16}$ inches; consequently the greater part of the image could be projected at the same time on to the plane containing the slit of the spectroscope. This instrument consisted of three compound prisms of Hofmann mounted by Simms, and giving a dispersion equal to some four or five prisms of 60°.

The shortness of the time of totality rendering it impossible to take many readings of the positions of lines with the graduated arc, a long slit furnished with a reflecting prism, kindly made for the Eclipse Expedition by Mr. Browning, was therefore adapted to the spectroscope by my assistant Mr. HOSTAGE, so that the observed lines might be rapidly compared with the bright lines in one of Mr. Lockyer's vacuum tubes.

No bright lines were seen, though the slit was set as wide as possible, so as not to lose the dark absorption lines of the spectrum; the observation was made through cirrus clouds.

These tubes consisted of a hydrogen vacuum with Fe. and Mg. poles, one of which was tipped with Na.; they consequently gave the bright lines C, F, G, *h*, *b*, D, and a line nearly half-way between D and *b* (not yet accurately determined). The slit was 1⅝ inch long, and the reflecting prism ⅛ inch long. The battery used with these tubes consisted of two large bichromate of potash cells made by Apps, and the induction coil was one of Ladd's.

As the morning of the 22nd was so unfavourable, I thought it more prudent to change the long slit even after first contact, in order that I might work with the more delicate slit belonging to the instrument. I thus felt more certain of having the adjustments perfect; but I had to sacrifice the advantage of the vacuum tubes.

As the eclipse advanced, ... I adjusted the opening of the slit upon the sun itself while partially covered by clouds. The slit was left as wide as possible, but so as not to lose the dark absorption lines of the spectrum. . . . . .

Thick clouds obscured the sun at first contact, so that I could not observe it by the extinction of the bright lines of the chromosphere.

Perry's observation.

When totality commenced, Mr. HOSTAGE was keeping the slit just outside the moon's limb, and then by moving the telescope in azimuth varied the position of the slit until it was at about a diameter from the lunar disc.

I swept along the graduated arc with the eye-telescope many times during the greater part of totality, but could not detect a single line at any point of the corona on which the slit was placed. The only light that penetrated my prisms was a possibly faint glimmer.

Captain TOYNBEE was calling the time during totality, and I began at last to fear that if I kept my eye longer at the spectroscope I should observe nothing at all. I then looked up for the first time since the commencement of totality, and saw that the corona was covered by cirrus clouds. There was a narrow rim of light of a pale white around the limb, equal in breadth to one-fifth of the lunar radius, and this ring as seen through the clouds was certainly not more than one-eighth of the brilliancy of the moon's surface on a cloudless night. Receding from the limb, the light faded off, at first gradually and then rapidly. It could be traced to the distance of about seven-eighths of the moon's diameter.

Mr. B. E. Hammond.

36 38 N. } PUERTO DE STA. MARIA, SPAIN,
6° 10' W. } 22nd December, 1870.

MS. Reports of the 1870 Expedition.

Instrument—Integrating direct-vision spectroscope.

A spectrum, in which the red and green were present, but the blue and violet absent; and upon the red a somewhat ill-defined line of brighter red. Quite sure that there was no green coronal line.

The instrument I employed was one of Browning's direct-vision spectroscopes, with seven prisms, not fitted to a telescope, but receiving the light of the corona directly on the slit.

After thirty or forty seconds of totality had elapsed, I directed the spectroscope to the corona—the slit being about ·005 in. wide; but with a slit of this width no light passed through the prism.

Accordingly I enlarged the slit to about a width of ·025 in., and

Diagram to illustrate the spectrum observed by Hammond.

directed it to the corona again, and then saw a spectrum in which the red and green were present, but the blue and violet absent, and upon the red

was a line of brighter red, of course somewhat ill-defined from the width of the slit, but much brighter than the remainder of the spectrum.

I could find no other bright line in the spectrum.

I continued during quite thirty seconds to direct the spectroscope to the corona, and always saw the same spectrum, and one red line only, which I feel sure must have been C.

The one fact of which I am quite sure is that the red line was visible, and that the green coronal line was not.*

The Rev. R. Abbay.

36° 43′ 56″ N. } JEREZ DE LA FRONTERA,
6° 10′ 8″ W. } 22nd December, 1870.

MS. Reports of the 1870 Expedition, and Monthly Notices of the Royal Astronomical Society for January 13th, 1871.

Instrument—An integrating spectroscope with two prisms of 45°. Angle of integration 7°.

The instrument with which my observations were made was kindly lent to me by Professor C. A. YOUNG, of Dartmouth, U.S. It consisted of two prisms of 45° each, with refractive index of 1·68, the faces of each prism being 2¼ by 2⅝ inches.

As totality approached, the dark Fraunhofer lines slowly disappeared, leaving a dull spectrum which faded away; then C, D, and F were seen bright for 8 or 10 seconds; after which, C and D disappeared, leaving F, and a line between 1464 and 1494. There was a great amount of cloud.

The diameter of the lenses of collimator and telescope was 2¼ inches, the focal lengths being 17 inches, and the field of view about 7°.

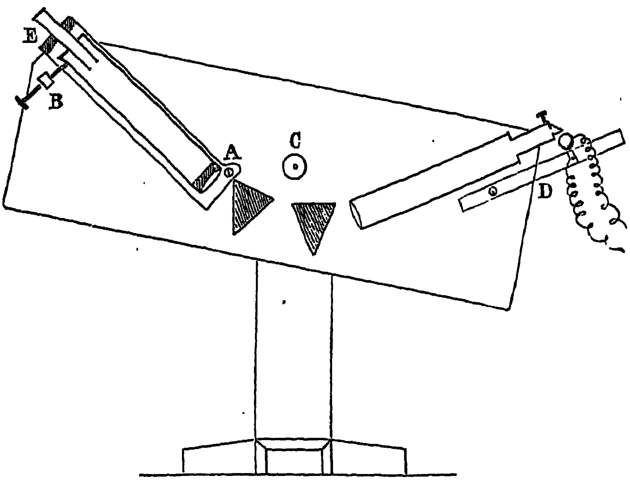
The collimator and the prisms were fixed once for all on a large solid board. The telescope was fixed on a piece of wood, movable about a screw (A), by means of a micrometer screw (B). Attached to the piece of wood carrying the telescope was a pricker passing over a sheet of tinfoil, so that the distance between any two given lines of the spectrum might be measured.

A single screw (C), held the instrument to a horizontal piece of wood, so as to allow a slight motion in a vertical plane; and by means of a vertical axis motion was also obtained in a horizontal plane.

* Professor YOUNG, in a letter dated the 7th August, 1871, says: "I am disposed to think that the telescope of Mr. HAMMOND's spectroscope was in focus for the red, and not for anything else. At any rate, it seems to me that the fact that he did not see D_3 nor F, either of which ought to be conspicuous enough in a good instrument well adjusted, deprives his merely negative evidence as to 1474 of much weight.

Abbay's observation.

Two arms of wood were fitted on parallel to the collimator, so as to support the vacuum tube in a convenient position. At the back of the piece of wood represented by shaded lines at E, pieces of tinfoil were gummed, so that when a micrometer screw was turned, the sheets of tinfoil passed beneath a pricker, and the different lines could be exactly marked by dots, and the intervals afterwards measured. The slit was about ⅛th inch in length (nearly one-half of it being covered by the prism used for reflecting the light from the vacuum tube into the collimator), and was placed in a horizontal position. . . . . .



Integrating spectroscope used by Abbay.

A short time before totality began I arranged the slit so that the D lines just appeared as a single thick line. . . . . .

At 11.44, Jerez time, I noticed the B line extremely black. As totality approached, the dark Fraunhofer lines slowly disappeared, leaving a dull spectrum, which also faded away. Directly after the signal of totality I noticed the C, D, F lines extremely bright for eight or ten seconds, having time to compare them with the same three bright lines given by the vacuum tubes.

Commencement of totality.

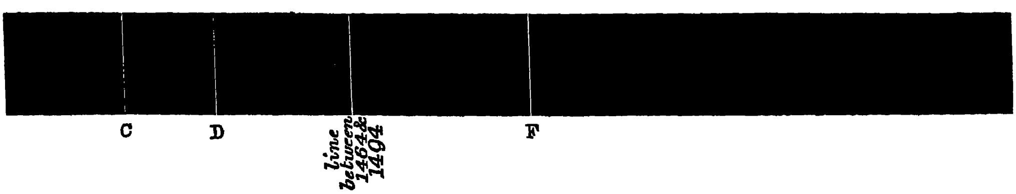


Diagram to illustrate the spectrum observed by Abbay.

C and D then disappeared, leaving F and another line (rather brighter than F) some distance on the less refrangible side of *b*.

After some trouble, I succeeded in placing the cross-wires very nearly on the bright line, and determined not to move the telescope during the rest of totality.

No other lines appeared, although the C line of the vacuum tube was in the field on the one side, and the F line on the other. Abbay's observation.

There was no continuous spectrum; the lines were bright on a dark ground, and when I turned off the vacuum tubes the two bright lines were left alone in the field.

I did not sweep away beyond F or C after I had placed the cross-wires on the bright line.

I noticed no reappearance of C and D at the end of totality.

On the reappearance of the dark lines after totality, I found that the cross-wires were on the vacant space between the lines 1464 and 1494 of Kirchhoff's scale.

The measurement was as accurate as it was possible to obtain with the instruments used, but I cannot say with certainty that the bright line seen was absolutely coincident with the 1474 line.

In order to give you an idea of the dispersive power of the prisms, I may mention that after totality I tested the instrument by means of the light of the dull, heavy clouds which obscured everything, and found that I could not separate the D lines, but was able to obtain four thick lines like bands between E and *b*. I also saw 1464 and 1494 as single thick lines. Dispersive power of spectroscope.

By a rough calculation, from the number of threads of the screw and the distance through which it was turned in bringing the jaws of the slit into contact, I came to the conclusion that it was from $\frac{1}{250}$ in. to $\frac{1}{200}$ in. wide.

There was a great amount of cloud and wrack flying, and it was only through a rift in the cloud that I obtained a view of the corona.

As there was no continuous spectrum, I of course saw no dark lines.

Mr. Walter Pye. 36° 43′ 56″ N. 6° 10′ 8″ W. JEREZ DE LA FRONTERA, 22nd December, 1870.

"Coast Survey Reports for 1870," Appendix No. 16.

Instrument—An integrating spectroscope.

(p. 34.) A star spectroscope* with a single prism of extra dense yellow glass having a refracting angle of 60°. The telescope and collimator had each an aperture of 23^{mm} and a focal length of about 180^{mm}.

* The description of the instrument is by Prof. YOUNG.

Pye's observation. Description of instrument.

Its dispersive power was such that it showed without much difficulty the four lines of *b* distinct and separate. It was provided with the registering apparatus of Prof. WINLOCK, and was mounted on the same general plan as Mr. ABBAY's; but to secure more light, at the same time allowing the slit to receive its illumination from the whole coronal region, I employed the following device: A small telescope, magnifying about $2\frac{1}{2}$ times, with a field of about 7°, was carefully adjusted for distinct *distant* vision of a remote object—*i.e.*, so that the rays from any portion of the object, after emerging from the eyepiece, should be exactly parallel to each other. This being placed in front of the spectroscope, its effect is not to form an image on the slit and thus restrict the observed spectrum to that of some particular portion of the coronal region, but simply to magnify the angular area from which the light proceeds to a diameter of about 4°, and thus to increase the light nearly sixfold.

A great number of bright lines seen for about $\frac{1}{8}$th of a second at the instant of totality. Then the bright lines C, D^3, 1474, F, and a faint line less refrangible than 1474, seen for an instant. The estimated relative brightness of the lines was C, 8·5—D_3, 5·5—1474, 10·0—F 3, continuous. Spectrum without dark lines seen when the slit was opened.

(p. 34.) [Mr. PYE says,] At the first instant of totality a great number of bright lines were seen—the effect being as if all the dark lines of the spectrum were converted into bright ones; these lasted only for an instant, and were seen with the slit nearly closed.

Then with a wide slit the following lines were observed: (1) C, very

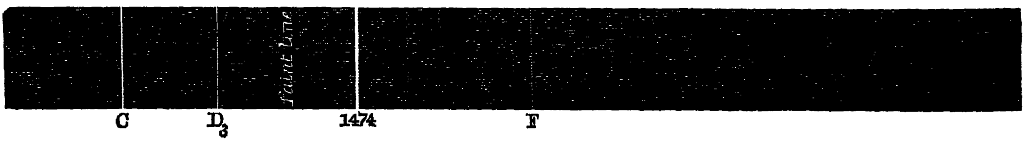


Diagram to illustrate the spectrum observed by Pye.

bright; (2) a bright line near D, probably D_3; (3) No. 1474—by far the brightest of all—peculiarly sharp and distinct; (4) F, the faintest, but sufficiently distinct.

A very small bright line also seemed to appear near 1474 for an instant, but as it could not be seen again its existence is doubtful.

The estimated relative brightness of the lines was C, 8·5, D_3, 5·5, 1474, 10·0, F, 3·0.

(*Supplementary Explanations given to Prof. Young.*)

1. For about two minutes before totality the eyes were shaded according to your directions.
2. I should imagine that the duration of the number of bright lines

was not longer than was sufficient to produce an impression on the retina, or less than one-eighth of a second. Pye's observation.

3. I had in no way been prepared to expect this phenomenon (*the reversal of the Fraunhofer lines*).
4. No continuous spectrum was seen after totality until the slit was opened, when it could be easily seen; at neither time were any dark lines observed.
5. The slit was opened until the regulating screw did not act upon it —about $1\frac{1}{2}$ turns of the screw.* The *b* lines would certainly have appeared as a single line, and probably indistinct.
6. The small bright line near 1474 was nearer than it to the red—that is, to the left of the register plate. It should be mentioned that it was just at the close of the totality that it was looked for again, when it could not be found.

Article in "Nature" by Professor YOUNG, describing the spectroscopic observations of the American eclipse party stationed in Spain. "Nature," Vol. iii. p. 261.

By my direction Mr. Pye recorded the brightness of the lines which he saw during totality on an arbitrary scale from 10 down. These are his numbers :— Calculation as to the height of the area emitting the 1474 line.

C, 8.5. D_3, 5.5. 1474, 10. F, 3.

I suppose the actual amount of light of each kind would be roughly proportional to the squares of these numbers, for we seem instinctively to call one luminous object twice or thrice as bright as another, when it would give the same light at twice or thrice the distance.

If so, the numbers representing the relative amounts of light would stand, C, 72, D_3, 30, 1474, 100, and F, 9, neglecting fractions.

Now in the analysing spectroscope the case is very different, and it is difficult to make an accurate estimate; but I think those who have been accustomed to observe both C and 1474 would admit that their ratio of brightness is something the same as that between a first and fifth magnitude star—*i.e.*, C is at least twenty-five times, and perhaps fifty times,

* (*Note by Prof. Young.*) Subsequent careful measurement showed that the screw ceased to act upon the slit when its width was very approximately 0·2 of a millimeter.

Prof. Young on Pye's observation.

as bright as 1474. Even during the totality 1474 can hardly be called conspicuous in an analysing instrument, while C blazes like a red Sirius. It seems necessary, therefore, to assume that the area which emits the 1474 light is to the area which gives C roughly in the proportion of 100 by 25 (or 50) to 72—that is to say, the angular area of the self-luminous corona is from 35 to 70 times as great as that of the red stratum of hydrogen and prominences combined. I suppose these taken together would be about equivalent to a ring 15″ high surrounding the sun; and this would make the self-luminous corona equivalent to another ring from 8′ to 16′ high.

Of course I am aware that the numerical data of this calculation are very uncertain, and I have therefore neglected all considerations of shading and inequality of illumination.

Prof. J. Winlock. 36° 43′ 56″ N. } 6° 10′ 8″ W. } JEREZ DE LA FRONTERA, 22nd December, 1870.

"U.S. Coast Survey Report for 1870," Appendix 16.

Instrument—An equatorial telescope of $5\frac{1}{2}$ inches aperture, and about 7 feet focal length, made by Alvan Clark; no clockwork; finder of $2\frac{1}{2}$ inches aperture. Spectroscope by Troughton and Simms, with two prisms of flint-glass, and a recording apparatus.

Corona observed through passing clouds. At a distance of 12′ from the sun a continuous spectrum and four bright lines registered. Slit moved to a distance of 25′ from the limb; the lines faded out nearly together—1474 being somewhat the most persistent. No dark lines observed. The bright lines were C, near D, 1474, and F.

(p. 26.) The cross-wires of the finder were carefully adjusted the evening before the eclipse, so that when the finder was pointed on a star, its spectrum would appear in the spectroscope. I adjusted the width of the slit by faint clouds or patches of blue sky, so that if dark lines were present they could not escape me, and a faint continuous spectrum might not be cut off.

Mr. ALVAN G. CLARK, whose skill in everything pertaining to a telescope ensured careful and judicious management of the instrument, was stationed at the finder to direct the telescope to the parts of the corona which were to be examined, and at the same time to observe incidentally general phenomena. Mr. CLARK took his place at the finder just before the beginning of the total phase. On the instant of totality he directed the telescope, according to my instructions, upon the faint part of the corona, about 12′ from the edge of the moon, and seized every oppor-

tunity offered by openings among the clouds previous to the reappearance of the sun, to obtain for me a view of the coronal light unmixed with reflected rays. He several times reported, "Now it is clear here;" and on looking into the spectroscope I saw a continuous spectrum, not very faint, with four bright lines. Observation made through gaps in cloud.

The appearance remained unaltered, except in brightness, as Mr. CLARK moved the instrument from point to point of the corona. I carefully registered these lines on the silver plate, and then requested Mr. CLARK to move the instrument away from the sun until the lines should disappear. As he did so, I tried to note the order of disappearance of the lines. They all disappeared nearly at the same time, having previously faded out together—one of them, which proves to be that known as 1474, seeming to be somewhat more persistent than the rest. When the lines had all vanished, Mr. CLARK reported that the instrument was pointed about 25′ from the sun. 1474 traced to a height of nearly 25′.

The double-threaded screw which moved the telescope of my spectroscope enabled me to sweep rapidly from one end of the spectrum to the other. During my examination of the corona I looked carefully for dark lines, and saw none. I examined critically the whole region above F, and saw nothing but a continuous spectrum. I looked for lines here because I had seen broad lines near H in 1869. No dark lines seen.

Some standard solar lines had been registered on the silver plate before the total phase; and the plate had been moved, as has been described, to receive the lines of the corona. After the total phase, the principal lines of the solar spectrum, as high as F, were again registered.

The cross-wires in the spectroscope had been made very coarse, for fear that it would be difficult to see them. No such difficulty was found; and with finer wires the precision of the pointings upon the lines might probably have been somewhat increased. But no considerable error can have occurred, since the dark lines registered before the total phase agree well with those registered after it, and the same lines ruled on mica at the present time can be superposed on those recorded upon the plate, which have, in fact, thus been identified. Positions of lines observed.

An examination of the silver plate shows that the coronal lines observed were C, a line near D, 1474, and F. C and F agree exactly

Winlock's observation.

with the dark lines. The line near D is less refrangible than the sodium line D, by a difference greater than I suppo sed the error of observation

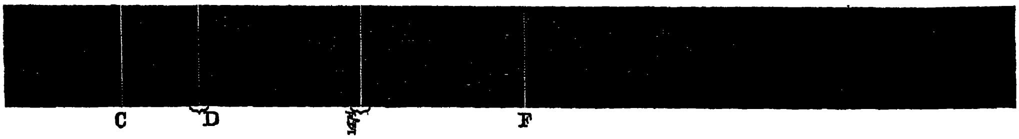


Diagram to illustrate the spectrum observed by Winlock.

could be. Line 1474 is ruled a little more refrangible than Kirchhoff's line—perhaps not more than can be attributed to an error of observation under the circumstances.

Article on the American Eclipse Expedition, by Prof. S. P. LANGLEY in "Nature," Vol. iii., p. 229.

Prof. J. WINLOCK, using a spectroscope of two prisms on a 5⅓-inch achromatic (directed by Mr. A. CLARK at the finder), found a faint continuous spectrum, without dark lines.

1474 followed all round the sun to at least 20′ from the disc.

Of the bright lines the most conspicuous was 1474 Kirchhoff, which was followed all around the sun to at least 20′ from the disc. It may be here remarked that all the spectroscopes showed this as much as the most conspicuous coronal line. A number of other lines were also noted, and their position recorded by the apparatus devised by Prof. WINLOCK.

Prof. C. A. Young.

36° 43′ 56″ N. } JEREZ DE LA FRONTERA,
6° 10′ 8″ W. } 22nd December, 1870.

"Coast Survey Report for 1870," Appendix No. 16.

Instrument (p. 27)—An equatorial telescope (by Merz and Sons), of 2^m 64 focal length and 0^m 162 aperture, provided with clockwork and the usual accessories.

A spectroscope, by Clark and Sons, specially fitted to the abovenamed telescope, and having the dispersive power of thirteen prisms of 55° each. Its telescope and collimator have each an aperture of 23^{mm} and a focal length of 177^{mm}. It is the same instrument described in the "Journal of the Franklin Institute" for November, 1870, where it is figured.

This instrument was provided (at the expense of the Government appropriation) with Prof. WINLOCK's beautiful arrangement for registering the position of spectral lines.

At the commencement of totality the slit was placed tangentially to the E. limb. The spectrum faded away, and for about 2″ the field was filled with bright lines, which appeared to be arranged in groups similar to the ordinary Fraunhofer lines. The slit was then moved, and 1474 was traced to a distance of about 16′ from the sun's limb, C and D were traced to 4′ or 5′ from the limb, F not quite so far. A faint continuous spectrum was seen, with no dark lines. On the W. limb 1474 was traced to a distance of 13′, on the N. to 12′, and on the S. to 10′. A prominence was examined, and 20 lines were recorded.

(p. 28.) For the observation of the eclipse I used the large equatorial [mentioned above], armed with the Clark spectroscope. The telescope is a very good one. The spherical aberration is very nicely corrected, but the correction for colour is somewhat overdone (as is the case with most of the Munich glasses), the focus for the C line being about 15^{mm} nearer to the object-glass than that for G. This is, however, of comparatively little importance in spectroscopic observation. . . .

(p. 29.) A small piece of card, with an orifice in its centre, was fastened over the slit, and no other finder was necessary, as even during the totality the image thrown upon the card was abundantly bright to enable me to point to any desired portion of the corona with perfect certainty.

A little mirror was attached to the brass carrying-rod, and so arranged that with one eye I could see in it the card and the image upon it, while the other was at the eyepiece of the spectroscope. . . .

(p. 30.) I had previously laid down for myself the following programme:—

Programme.

1st. Observation of 1474, and ascertainment of the distance to which it could be traced from the sun's limb.

2nd. Examination of the corona spectrum for other bright lines, as well as for dark lines, and the registry of any that might be found.

3rd. Examination of the extension of the chromosphere lines outward and inward upon the disc of the moon.

4th. Examination of the spectrum of a prominence, if time permitted, in order to find lines invisible except during an eclipse.

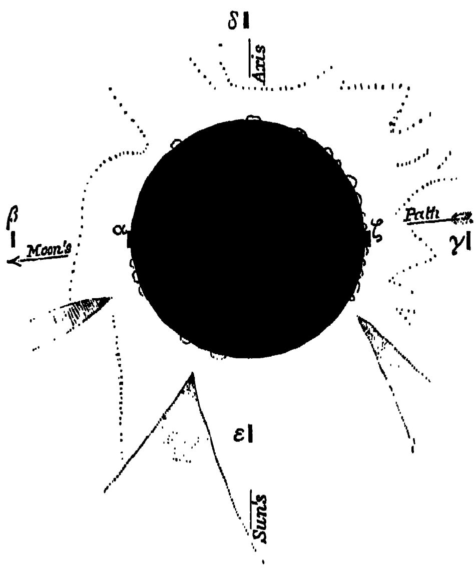


Diagram constructed to show the positions of the slit during Young's observations.*

* A drawing from which the above diagram has been made was submitted to Prof. YOUNG and approved by him; the outline of the rifts and corona is taken from the Syracuse photograph.

Young's observation, 1870.

In accordance with the programme, as soon as the sun came out into the clear sky, I had adjusted the slit of the spectroscope accurately tangential to the limb of the sun at the point where the last ray would vanish, and brought the 1474 line to the cross-wires. It was already plainly bright, the atmospheric glare being so much reduced as to make it perfectly easy to see.

The lines of *b* were also distinctly reversed, as were several of the iron lines near E; and I even thought that I could see the three chromium lines which I had found the day before.

Reversal of lines.

Very soon, as the crescent grew narrower, they shone out unmistakably, and all the other lines I have mentioned became continually more conspicuous, while the dark lines of the spectrum and the spectrum itself gradually faded away: until all at once, as suddenly as a bursting rocket shoots out its stars, the whole field of view was filled with bright lines more numerous than one could count.

The phenomenon was so sudden, so unexpected,* and so wonderfully beautiful, as to force an involuntary exclamation. Gently and yet very rapidly they faded away, until within about two seconds, as nearly as I can estimate, they had vanished, and there remained only the few lines I had observed at first.

Of course it would be very rash, on the strength of such a glimpse, to assert with positiveness that these innumerable lines corresponded exactly with the dark lines of the spectrum which they replaced; but I feel pretty fairly confident that such was the case.

Grouping of bright lines seemed familiar.

The grouping of the lines seemed perfectly familiar, and so did the general appearance of the spectrum; except that the lines which had been visible before the totality were relatively far too conspicuous.

* (*Note by Prof. Young.*) It was unexpected simply because it had not been seen in 1868[1] and 1869. In 1869, having been led to expect something of the kind by Father SECCHI's report of a layer close to the sun's surface, giving a continuous spectrum, I looked for it very carefully, but failed to see it; so that on this occasion I was wholly unprepared.

I now suppose that my previous failure was due to my having worked with a *radial* slit; in this case the lines would be so short (from 0·5″ to 1·5″) that they might easily escape observation.

[1] See the note to RIHA's observation on p. 384. For three or four seconds towards the end of totality, in 1868, RIHA saw what he described as a discontinuous spectrum crossed by great dark stripes; but the meaning of his observation does not seem to have been recognised at the time, and it remained for YOUNG in 1870 to re-observe the bright-line spectrum, and properly to describe and interpret his observation.

As soon as this bright-line spectrum had vanished, I gently pressed against the side of the telescope tube, and forced the slit away from the image of the sun towards the east. All the lines in the field (the four lines of *b*, the three chromium lines, and two or three iron lines near E) immediately disappeared, except 1474, while this continued bright, though of course growing fainter as the distance from the sun increased; but by opening the slit somewhat I could trace it to a distance from the limb of more than the sun's radius, or about 16′, as determined by a glance at the card attached to the spectroscope, upon which the image of the eclipse was distinctly and beautifully visible. Light flocculi of cloud were continually and swiftly drifting over it. **Young's observation, 1870.**

By touching the tangent screw, the C and D_3 lines were then brought into the field of view, and their behaviour examined. So long as the slit was in the chromosphere they were dazzlingly bright; but as soon as the slit was removed from this they became *suddenly* fainter, although I could trace them to a distance of 4′ or 5′ outside of the sun, and even upon the disc of the moon. F was then tried, and behaved similarly, except that, being less brilliant, I could not follow it so far. I have no doubt, however, that their extension beyond the limits of the chromosphere was due to reflexion from the haze and flocculi of cloud above mentioned, as I saw nothing of the sort in 1869, in a clear sky.

A faint continuous spectrum, much brighter near the sun, always formed a background for the bright lines. I saw no traces of dark lines in it, though I looked for them carefully. **Continuous spectrum of corona; no dark lines seen.**

1474

Diagram to illustrate the spectrum of the corona observed by Young.

Besides 1474, no other lines were seen which behaved in a similar manner, or could possibly be due to the corona.*

* (*Note by Prof. Young.*) Father Secchi, in a note published in the "Astr. Nachr.," vol. lxxvii., p. 159, says: "Mon collègue le P. F. Denza, directeur de l'observatoire de Moncalieri, observa avec un spectroscope que j'avais convenablement disposé, deux raies brillantes dans la couronne—une près de la E de Fraunhofer, l'autre au milieu entre le vert et la jaune. Faute de temps, on ne pût pas mieux fixer la position." The one near E was evidently 1474, and it would seem pretty likely that the other, "half-way between the green and the yellow," might be one of the two faint lines which I saw in 1869, and *doubtfully* reported as corona lines.

Young's observation, 1870.

(p. 32.) Resuming the spectroscope, I examined hastily the other portions of the sun's circumference, to determine the extent of the corona shown by the 1474 line, and with the following results:—On the west limb I traced it to a distance of 13′, on the north 12′, on the south 10′. A few moments still remaining, I took a hurried glance at the spectrum of the chromosphere on the western edge, in order to look for new lines, but found none. I saw the following:—C, D_1, D_2, D_3, 1474, 1515, 1519, 1601, 1605, 1607, b_1, b_2, b_3, b_4, 1990, 2001, 2003,

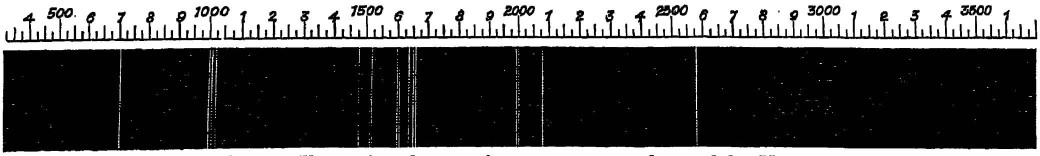


Diagram illustrating the prominence spectrum observed by Young.

2031, F, and 2581·5—twenty in all. The examination was not extended below C nor above 2581·5; for while I was looking at the last-mentioned line, and before I could bring it to the centre of the field, the sun emerged. I was somewhat surprised and disappointed at not finding any new lines; perhaps a closer scrutiny with a somewhat widened slit might have been more successful.

Lines above *b* not cut upon register-plate.

I ought to add that the positions of the lines above *b* were determined only by my general knowlege of that portion of the spectrum, and the fact that the lines named are often observed there. I did not have time to bring them accurately to the cross-hairs and cut them upon the register-plate. I hurried the observation in order to catch, if possible, at the close of the eclipse, the same reversal of the Fraunhofer lines which I had seen at the beginning. But I was not quick enough, and as the slit was not in the proper position, I did not see it.

Article by Prof. Young in "Nature," Vol. iii., pp. 261-2.

(p. 261.) Some of the observers, favoured with a less clear sky than we at Jerez, saw the C and F lines even on the moon, undoubtedly by reflexion from thin clouds. I saw myself the C line as far as 6′ or 7′ from the sun, far above any possible hydrogen atmosphere.

Therefore, although Prof. WINLOCK and myself both saw the 1474 line to a distance of more than 16′ from the sun, I should not dare to lay much stress on that observation as showing the true limits of the self-luminous coronal matter. . . . . Young's observation, 1870.

(p. 262.) The question has been raised whether the corona line *exactly* coincides with the 1474 dark line in the solar spectrum. The difference, if any (and I have not found the slightest reason to suspect the least want of coincidence in observations with the whole dispersive power of thirteen prisms), is less than one-tenth of one division of Kirchhoff's scale. Coincidence of coronal line with 1474.

Just before the totality began, I placed the slit of my spectroscope exactly tangential to the sun's limb at the point which would be last covered, and brought the 1474 line, already bright, as is usually the case at the base of the chromosphere, exactly to the cross-hairs. After the totality had fairly begun, I moved the equatorial in right ascension until the slit was more than 16′ east of the sun's limb; and the line remained continually visible, though of course growing fainter as the distance from the sun increased. There is not the slightest possibility of mistake nor of error beyond the limit named—*i.e.*, one-tenth of one division of Kirchhoff's scale.

Mr. C. E. Burton. 37° 14′ 20·6″ N. 15° 13′ E. } AUGUSTA, SICILY, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

Instrument.—Telescope, a five-inch equatorial. Spectroscope, a Herschel-Browning of the usual kind, with two right-angled prisms.

(p. 3.) Early on the morning of the 22nd the finder was got into adjustment, and the slit of the spectroscope was opened to such a width that the maximum of light was admitted which permitted *good* definition of the principal solar lines—say fifty or sixty in number. D was well separated, and the prominence line near it was distinctly divorced from D_2. Just before totality about 25 lines were seen in the spectrum of the chromosphere, at the lower horn. During totality the slit was tangential to the east limb. One line a little less refrangible than E was observed; the field of the spectroscope was not perfectly dark.

(p. 4.) A comb was inserted in the eyepiece of the spectroscope, and a careful diagram of the solar lines referred to this was made for use during totality, at which time, however, it was utterly invisible from want of light, so that the position of the bright line rests merely upon a careful estimate of its place in the field.

Burton's observation.

(p. 11.) It was intended to have observed the four following points in order: viz., the east, west, north, and south points. Owing to a passing cloud, the first point alone was examined.

The slit had been previously placed north and south, so that the corona would be viewed at the first pair of points tangentially to the moon's limb, and at the second pair of points the slit would be radial to the moon.

Immediately on the commencement of totality the tangential slit was placed as near as possible to the east point of the moon's limb; for two or three seconds I saw nothing in the spectroscope, but after carefully shading my eyes for two or three seconds, a line was distinctly made out very near E. My impression is very strong that it was a little less refrangible. It was less defined than the hydrogen lines of the protuberances which had been studied during the morning.

. Diagram illustrating the spectrum of the corona observed by Burton.

I saw no decided continuous spectrum, but the field was not perfectly dark. No dark lines were seen in the corona spectrum. . . .

Bright lines seen at cusp before totality.

Just before totality, about twenty-five lines made their appearance in the chromosphere at the lower horn.

They were chiefly situated between D and E. The two most refracted lines of it were beautifully reversed a little before this time.

Padre F. Denza. 37° 14′ 20·6″ N. 15° 13′ E. } AUGUSTA, 22nd Dec., 1870.

"Rapporti della Commissione Italiana," pp. 61-3.

Instrument—A refractor of 108^{mm} aperture and 1^{m} 624 focal length, and spectroscope of one flint-glass prism of 60°.

In the spectrum of the corona two lines between E and D were observed. The position of the brightest was estimated to be between 1463 and 1467. The other was near to 1246. These were seen upon a background of con-

(p. 61.) Non appena ebbi adattato l' occhio allo spettroscopio, che due righe nitidissime e molto ben distinte mi si mostrarono nel campo del medesimo. Ambedue erano comprese nella zona dello spettro posto tra la E e la D. La prima, assai vivace, si trovava nella regione del verde presso la E, ma non nella sua stessa posizione, e la seconda meno splendida, era presso il limite di questa regione e quella del giallo. Il fondo, su cui si proiettavano le due righe, era di un verde scuro, il quale diveniva più chiaro e

tendente al giallo nell' avvicinarsi alla seconda riga. Nel rimanente campo dello spettroscopio, e massime del lato dei colori meno rifrangibili, mi sembrò intravedere la continuazione dello spettro continuo, ma debolissimo.

tinuous spectrum The spectrum of a prominence was also examined, and other brilliant lines in the red and yellow were seen—proving the former spectrum to belong to the corona.

Però una fortunata combinazione mi diede agio a rendermi pienamente

Diagram illustrating the spectrum of the corona observed by Denza.

convinto che le due righe da me osservate appartenevano realmente alla corona. Invero, mentre De-Lisa faceva muovere lentamente il Refrattore, mi apparvero nello spettroscopio brillantissime righe lucide nel rosso e nel giallo, e mi parve di vederne alcune eziandio nel verde. Lo splendore di queste righe era di gran lunga maggiore di quello delle due viste prima: esso era troppo forte pel mio spettroscopio e per l'apertura larga che io aveva dato alla fessura. Sia dalla posizione di si fatte righe, come dalla loro luce vivissima, non tardai ad accorgermi che esse appartenevano allo spettro delle protuberanze. Perciò non prestai grande attenzione a questa osservazione, spettando ad altri l' esame spettrale delle protuberanze, ed avvisai tosto De-Lisa di muovere il Cannocchiale in senso contrario affinchè ritornasse nel mio strumento lo spettro della corona. Difatti mi ricomparvero immediatamente le due righe di prima, che io potei mirare ancora per pochi istanti; ma questa seconda volta mi sembrarono più sbiadite di prima, forse perchè viste subito dopo le vivacissime delle protuberanze; nè mi rimase tempo di confrontarle colla scala. . . .

Spectrum of prominence.

(p. 62.) Appena terminata la fase totale, non essendomi riuscito di riferire la posizione delle due righe osservate alle divisioni della scala vicina, le tracciai immediatamente sullo spettro dipinto che aveva presso di me, per poterne fissar bene la posizione. Feci ciò con grande attenzione, ed in modo che io credo ben poco discosto dal vero, perchè la impressione delle righe vedute mi era rimasta vivissima nella mente. I risultati da me ottenuti nel determinare la posizione delle due righe anzidette non possono al certo riguardarsi che come approssimati e nulla più. . . . Pertanto più tardi confrontai la posizione delle due righe da me tracciate con quelle delle tavole di Kirchhoff, di Angström, e di Van der Willingen. La più

Immediately after totality bright lines of corona carefully traced upon chart of spectrum.

Denza's observation.

splendida nel verde la trovai un po'meno refrangibile della 1474 di Kirchhoff. Essa mi risultò *assai prossima al gruppo di righe che nella scala di Kirchhoff è compresso tra le divisioni* 1463 *e* 1467. . . . .

(p. 63.) La riga gialla da me tracciata è posta quasi a metà distanza tra la E e la D; e presso al noto gruppo delle righe del calcio, un po' più verso la E. *Essa sarebbe compresa tra la* 16 *e la* 17 *di Van der Willingen, e, secondo la scala di Kirchhoff, si troverebbe assai dappresso alla* 1246,* *che è l'ultima del gruppo che si vuole pure attribuito al ferro.*

Padre A. Secchi. 37° 14′ 0·6″ N. 15° 13′ E. AUGUSTA, 22nd Dec., 1870.

"Rapporti della Commissione Italiana," p. 20.

Spectrum of cusp examined. Field of spectroscope seen to be full of dark lines, which Secchi at first thought must be caused by dust upon the slit, but, on examination, he found that they were parallel to the length of the slit. Spectrum of cusps examined again after a minute or two. Fraunhofer lines seen as more marked and nebulous than before.

Messa la punta del corno inferiore sulla fessura ebbi il campo spettrale tutto rigato di nero,† come se nella fessura fosse caduta una gran quantità di polvere. Sorpreso da questo fenomeno non diedi luogo alla riflessione e credetti che le righe fossero dovute realmente alla polvere, e mi misi con uno stecchino a nettare la fessura. Allora mi accorsi di due cose: 1ª Che la fessura era larghissima, cioè quale servita era al mattino per vedere le protuberanze a sole pieno; 2ª Che realmente le interruzioni non erano longitudinali, ma trasversali. Ritornai allora alla cuspide, ma non fu facile il metterla si presto sulla fessura, ed intanto essa punta si era già assai allargata. Le interruzioni non erano più cosi forti e decise e solo parevano linee largamente sfumate, onde senza intender bene il valore dell' osservazione passai a fare quello per cui io avea messo lo spettro-

* For other evidence with regard to faint lines which have been observed in this part of the spectrum of the corona, see pp. 348-50; see also the note upon p. 364.

† This observation no doubt corresponds with the observations of BURTON and NOBILE in 1870, and MACLEAR and HERSCHEL in 1871, all of whom saw numerous bright lines in the spectrum derived from the cusps of the thin solar crescent (see p. 337). In the "Astr. Nachr.," vol. lxxvii., p. 159, Padre SECCHI speaks of the first part of his observation as having been made one or two minutes after totality; and of the second part of it as being made some minutes after the first. He says: "Une minute ou deux après la totalité je fixai le spectroscope à la grande lunette de Cauchoix avec laquelle nous avions fait les photographies, et je visa à l'extremité des cornes de la phase; le spectre était très discontinu; je soupçonnai d'abord quelque dérangement, mais ce n'était rien; la discontinuité était très grande et visible, malgré que la fente fusse assez large, car elle était destinée à regarder la forme des protubérances et à en relever la différence avec celle que j'avais observée tout à l'heure. Quelques minutes après les cornes s'étaient élargies, cette discontinuité disparut."

scopio, cioè ad esaminare la forma delle protuberanze per confrontarla con quella che io avea veduto nella totalità. Esaminata questa tornai alle cuspidi e allora strinsi la fessura, ma in questa seconda ripresa non osservai nulla di singolare salvo che le righe di Fraunhofer vi erano più marcate larghe e sfumate, ma in genere non l' erano gran fatto più di quello che si vedono abitualmente in un bel giorno sereno.

Spectrum of cusp examined a second time.

Cosi mi sfuggi in parte una osservazione importante, cioè lo spettro della falce angustissima. Fu solo più tardi che riflettendo all' accaduto trovai che l'osservazione era il germe di una grande scoperta, cioè che lo spettro dell' orlo estremo del sole esser dovea di struttura diversa da quella che noi supponiamo, e forse tutto fatto di righe invertite. Ma era troppo tardi! Spero che i posteri suppliranno alla mia incapacità, e al non aver io saputo fruire di si bella occasione come avrei potuto.

Prof. W. Harkness. 37° 3′ 53″ N. 15° 16′ E. } SYRACUSE, 22nd Dec., 1870.

"Washington Observations" for 1869, Appendix 1.

Instrument—An analysing spectroscope, with 3-inch achromatic telescope, and spectroscope with one flint-glass prism of 60°.

(p. 48.) An achromatic telescope of 43·58 inches focal length, and 3·01 inches clear aperture, made by Alvan Clark & Sons, of Cambridgeport, Massachusetts. This instrument is provided with a large battery of eyepieces, ranging in power from 27·2 to 400 diameters. It is equatorially mounted on a very firm portable tripod stand, which can be adjusted to any latitude, except very low ones, and has a slow motion by which it may be moved through a few degrees in azimuth. The polar and declination axes are both provided with clamp screws; but there are neither divided circles nor tangent screws.

Slit placed upon the corona. 1474 was seen, and its position in the spectrum roughly measured. 1474 was then traced to a distance of not less than from 10′ to 15′ from the limb. Two other faint green lines were observed for an instant, and also the hydrogen spectrum—but this latter was probably from a prominence.

The finder which was originally furnished with this telescope, and which was used at Des Moines, had a clear aperture of only 0·68 of an inch. This seemed to me too small, so I discarded it, and substituted another having an achromatic object-glass of 8·87 inches focus and 1·20 inch clear aperture. It is provided with a direct eyepiece magnifying 10·0 diameters, and a diagonal one magnifying 6·3 diameters. Each of them has a field of view 3° 15′ in diameter. The pointing apparatus is the adjustable needle-point which was used at Des Moines.

Harkness' observation, 1870.

A single-prism spectroscope having the following optical constants:—

Small Telescope.	
Focal distance of object-glass . . .	6·55 inches.
Clear aperture of ditto . . .	0·86 inch.
Diameter of field of view . . .	5° 33′
Magnifying power	5·71 diameters.
Collimating lens for slit.	
Focal distance	6·52 inches.
Clear aperture	0·82 inch.
Collimating lens for scale.	
Focal distance	4·17 inches.
Clear aperture	0·82 inch.
Prism	
Refracting angle	60° 8′
Minimum deviation of line D . . .	47° 44′
Refracting index	1·613
Density	3·532

(p. 81.) Dropping the polariscope, I sprang to the spectroscope, and Captain Tupman directed it to the corona. I at once saw a green line, but the wind had blown out the lantern which illuminated the micrometer scale, and, in order to determine the position of the line, I seized my second lantern, which was standing in a sheltered place, held it to the spectroscope, glanced in, saw that the reading was about the same as at Des Moines in 1869, and before I could determine it accurately the wind blew out this lantern also, and I was deprived of all means of making exact

Diagram illustrating the spectrum of the corona observed by Harkness.

measures. However, there cannot be the slightest doubt that the line in question was the now famous 1474, whose wave-length is 531·6 millionths of a millimeter. Captain Tupman then directed the spectroscope to many different parts of the corona, and wherever the light was sufficiently bright to show anything I saw the same green line. It is difficult to say precisely how far I traced it from the sun, but certainly to a distance not less than from ten to fifteen minutes. Once I saw two other fainter green lines, of a less degree of refrangibility, which I am pretty confident also belonged to the corona. In addition to these, I several times saw a complete hydrogen

1474 traced to 10′ or 15′ from the limb.

Two lines less refrangibl[e than] 1474.

spectrum, and on each occasion, supposing it to be due to a prominence, I taxed Captain TUPMAN with having the needle-point of the finder near one of them. Once or twice he admitted that such was the case, but in one or two other instances he denied it. Feeling certain that the lines were produced by prominences, I paid little attention to the circumstance at the time; but on talking over the subject with the Captain afterwards, he assured me that on at least one occasion I accused him of having the pointer near prominences when such was not thecase. This puzzled me considerably, but after a little reflection I hit upon what I think is the true explanation. The slit of the spectroscope had a length of 0·20 of an inch, which, with the telescope employed, would give a field of view 15′ 46″ high. Hence, when the slit was radial to the sun, one end of it might easily be upon a prominence when the needle-point in the finder was 8′ distant from it. During the last few seconds of totality the thin cloud covering the sun became nearly dissipated, and the faint continuous spectrum of the corona became visible, but before there was time to examine it the totality was over.

Harkness' observation, 1870.

Captain G. L. Tupman. 37° 3′ 53″ N. 15° 16′ E. SYRACUSE, 22nd Dec., 1870.

"Washington Observations" for 1869, Appendix i.

(p. 117.) The first part of the corona that attracted my attention was a ray or enlargement in the right upper quadrant, a little to the right of the very bright protuberance A; but by the time you had done with the polariscope, which could hardly have been ten seconds, the left and lower left parts* B to C were the largest and brightest, and so they remained until near the end of totality, when the part D in the right lower quadrant almost, if not quite, rivalled them. . . . .

Position of Prof. Harkness' slit.

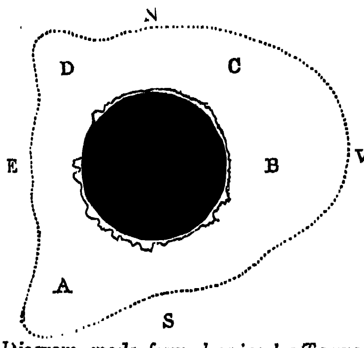


Diagram made from drawing by Tupman, showing the place of Harkness' slit.

(p. 118.) I endeavoured to keep the pointer at a distance of 8′ or 10′ from the

* Capt. TUPMAN is speaking of the inverted image. The diagram has been made from a woodcut given upon p. 117 of the "Washington Observations" for 1869, App. I. It has been turned to bring the north point uppermost, so as roughly to correspond with the other diagrams showing positions of slits.

Tupman's description of the position of Harkness' slit.

ring of prominences; but the vibration of the telescope being about 10′ on either side, the pointer oscillated between the limb of the moon and the outer part of the corona. I first placed it in the middle of the bright part B, then gradually moved it down to C, and eventually on to D. Once I moved it from B right across to A, but as you then said you could see nothing, I quickly went back to B. While examining the part D, the pointer remained very steady for several seconds opposite the middle of the interruption in the ring of prominences—the extreme point making about an equilateral triangle with the terminal protuberances.

Of the ninety-five to one hundred seconds that you observed the spectrum, the pointer was not ten near the ring of prominences. The spectrum of the chromosphere may have been very often visible when the slit was normal to the limb. From your exclamations at the time, I know that the outer limit of the corona gave a green line.

Dr. G. Lorenzoni.

37° 3′ 56·2″ N. } TERRANOVA,
14° 14′ 15″ E. } 22nd Dec., 1870.

"Rapporti della Commissione Italiana," pp. 101-6.

Instrument—A refractor by Merz of 11 centimeters aperture, mounted equatorially, with a direct-vision spectroscope by Hofmann, and an illuminated scale on which to read the positions of the lines.

In the spectrum of the corona a green line was observed, situated in the midst of a band of greenish light. The green line was estimated to be at 1463 of Kirchhoff's scale. The rest of the field of the spectroscope was not perfectly dark.

(p. 105.) La luce solare andava poco a poco estinguendosi; poi tutto ad un tratto venne a mancare. Allora nel campo dello spettroscopio comparve una banda di luce verdognola sfumata da una parte e dall'altra, ed in mezzo ad essa una riga benissimo marcata. Siccome non vedevo ancora lo spettro delle protuberanze domandai al Prof. Tacchini se l' Eclisse fosse incominciata, ed egli mi rispose affermativamente. . . . .

Lo spettro delle protuberanze da me veduto era costituito da linee lucide in campo oscuro. Le linee erano molte (più di venti certo): brillantissime e lunghe alcune, che riconobbi essere le tre prime dell' idrogeno e la D_3; tutte le altre erano sottilissime e più brevi delle precedenti forse di un terzo. Parrecchie di queste righe erano comprese fra la D_3 e la F; le altre si trovavano al di là della F: nessuna (almeno cosi mè parve) precedeva la D_3.

In quanto alla riga lucida in campo verde, essa apparteneva certamente alla corona. Quando terminata la totalità, ricomparve lo spettro solare, relevai che il suo luogo coincideva perfettamente con quello della riga 21 dello spettro di Van der Willengen (1463 di Kirchhoff).* La stessa conseguenza risulta anche dalle letture seguenti fatte alla scala. . . .

Position of the green coronal line.

1463

Diagram to illustrate the spectrum of the corona observed by Lorenzoni.

La tinta verdognola della larga banda in mezzo alla quale campeggiava la riga verde della corona, era assai bene visible; ma non è da credere per questo che il rimanente fondo del campo spettroscopio fosse perfettamente oscuro.

Prof. A. Nobile. 37° 3′ 56·2″ N. 14° 14′ 15″ E. } TERRANOVA, 22nd Dec., 1870.

"Rapporti della Commissione Italiana," p. 122.

Instrument—A refractor of 17·5 centimeters aperture, mounted equatorially with a spectroscope of one prism.

Lo spettro della corona non ha presentato a me che una sola riga lucida nel verde che corrispondeva probabilmente alla 1474 Kirchhoff,

Only one green line seen in the spectrum of the corona: it probably corresponds to 1474. This green line was seen for about 15s after the end of totality; Not less than 40 bright lines were seen at the cusps at least 5m before and after totality

1474 (probably)

Diagram to illustrate the spectrum of the corona observed by Nobile.

come risulta anche dalle misure prese. Questa appartiene al ferro, non ho veduta nessuna altra riga, quantunque le condizioni ottiche dei miei strumenti fossero buone, come risulterà da quello che sono per esporre. Non fu a me possibile discernere l' aspettata riga dell' aurora boreale. Debbo aggiungere che la riga brillante veduta nella Corona non spari al momento della ricomparizione del lembo solare, ma andò gradatamente

* LORENZONI gives the reading of his scale for the green line as 118·5. He gives the following readings for the D and *b* lines: D_1 73·2, D_2 73·6, b_1 133·5, b_2 134·8, b_3 135·2; and he estimates that the probable error of his reading for the green line would not exceed one-third of a division of his scale.

Green line seen for 15s after the end of totality.

spegnendosi durante circa 15s. dopo la fine della totalità.* Altro non ho a dire sullo Spettro della corona.

Mezz'ora prima della totalità ho pregato il Signor Witting di dirigere l' instrumento su uno dei cuspidi prodotti dalla Luna sul Sole. . . . .

Many bright lines seen at the beginning of totality.

Nel momento della totalità ed anche alcuni minuti prima le linee brillanti erano moltissime, ma occupato com'era alla determinazione della posizione della riga della corona non mi è stato consesso nè il tempo nè l' opportunità di stabilirne la posizione. Di certo non erano meno di quaranta e posso assicurare che nei cuspidi esse erano tutte visibili per almeno 5^m prima e dopo la totalità.

Mr. J. Norman Lockyer. — 12° 25′ N., 75° 0′ 6″ E. — Békul, 12th Dec., 1871.

"Nature," Vol. v., p. 218.

Instrument.—A 9½-inch reflecting telescope, focal length about six feet, mounted equatorially. Spectroscope, with one prism of 60° of dense flint. Collimator about 14 inches focus and 1½ inch aperture. Slit an inch long, with reflecting prism for comparison; spectrum from the centre of slit about one-eighth of an inch long.†

Spectrum of corona—C and 1474—thickening downwards. With 2nd instrument four rings not 2′ high, corresponding to C, F, G, and 1474.

I next tried the spectrum of a streamer above the point at which the sun had disappeared.‡ I got a vivid hydrogen spectrum, with 1474 (I

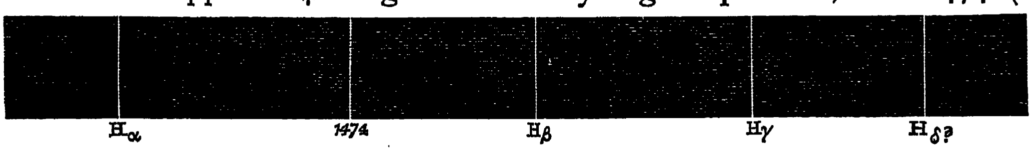


Diagram to illustrate the spectrum of the corona observed by Lockyer.

assume the position of this line from previous observation) slightly ex-

* Moseley in 1871 says that he watched the 1474 line for nearly half a minute after totality before it disappeared; but Moseley was using a direct-vision spectroscope of five prisms, which probably gave a larger dispersion than the single-prism spectroscope used by Nobile. Neither Moseley nor Nobile mention the distance of their slits from the limb at the time of their observations; and since the time of the disappearance would depend upon the purity of the atmosphere as well as the dispersion of the spectroscope and the breadth of slit, we cannot from these observations conclude that the 1474-light emitted by the corona of 1871 was more intense than that emitted by the corona of 1870. See remarks with regard to these observations on p. 374.

† The above information with regard to the instrument has been derived verbally from Mr. Lockyer; such a slit would give a breadth of spectrum corresponding to about 6′ of arc.

‡ Mr. Lockyer informs us that his slit ran along nearly tangentially at a height of about 7′.

tended beyond it, but very faint throughout its length compared with what I had anticipated, and thickening downwards like F. I was, however, astonished at the vividness of the C line and of the continuous spectrum, for there was no prominence on the slit. I was above their habitat. The spectrum was undoubtedly the spectrum of glowing gas.

Second Instrument—Naked eye, and five prisms of 45°, made of not very dense flint glass.

What I saw was four exquisite rings, with projections where the prominences were. In brightness C came first, then F, then G,* and last of all 1474·! Further, the rings were nearly all the same thickness, certainly not more than 2′ high; and they were all enveloped in a line of impure continuous spectrum. Observation with second instrument.

Captain Maclear.

12° 25′ N. / 75° 0′ 6″ E. — BÉKUL STATION, 12th Dec., 1871.

MS. Reports of the 1871 Expedition.

Instruments.—Two 6-inch refractors, mounted equatorially on the same pier, one being attached to either end of the declination-axis. To one of the telescopes, of 8 feet focal length, was attached a 6-prism spectroscope of great dispersive power, lent by Mr. Spottiswoode.

To the other telescope, of six feet focal length, was fixed a steel rod, on which pivoted a bar carrying, on one end, a 7-prism direct-vision spectroscope, and on the other an erecting eyepiece; either of these could at pleasure be brought into the principal focus of the object-glass, and retained there by a catch.

I worked myself generally with the 8-foot telescope; the slit was adjusted to give the solar absorption lines distinct, but not too fine. The moment of first contact was watched for in the spectroscope; but no About 3 minute before totality, while watching the northern cusp, with the slit radial, *b*, E, and apparently

As he speaks of 1474 thickening downwards, it would appear that his slit must also have been placed radially upon the corona.

* Query Hγ. The G line corresponds to 2854·2 of Kirchhoff's scale, while Hγ is about three times the breadth of the *b* group on the less refrangible side of G—viz., at 2795·7 K.

all the iron lines, became bright. The slit was then placed tangentially at the centre of the eastern limb, and the same bright lines were observed, together with several others. One of the lines, which was recognised as E (or near to E), was noticed to be brighter than the others; their number increased till all the Fraunhofer lines seemed to be reversed. No bright lines or spectrum was seen with either instrument when the slit was placed upon various parts of the corona.

change could be perceived, except that the limb appeared after contact serrated, as if the spectroscope slit were not in focus,—but this may have been fancy. During the next quarter of an hour I watched the northern cusp with the 6-prism spectroscope (slit tangential). C was bright the whole length; F bright and thin. I then turned the slit radial to the cusp, and observed four bright lines besides C close to it. Their positions were—three on the red side, within 20 units Kirchhoff (probably about 678, 682, and 688 K); and one on the violet side, within 6 units. Their lengths varied whilst I was watching, but not simultaneously. Their average height was about one-tenth the height of the spectrum; they were faint compared with C, and generally shorter.

The absorption bands generally, seen soon after sunrise, were as strong as usual.

At 6^h 51^m M. T. (25 minutes after commencement),* the cusp was evidently at a large prominence. I calculated its position at about N. 13° W., but its base extended over a considerable arc. C lengthened to half height of spectrum, but I did not see the other lines near it.

At 7^h 23^m (3 minutes before middle eclipse), when the cusp must have been about N. 35° E., watching with 6-prism spectroscope, slit radial to cusp, *b*, E, and a great many other lines—apparently all the iron lines—became bright, besides the lines already seen, viz., C, near D, and F. The light was then fast diminishing, and the bright lines were very distinct, and increasing in number. I called Mr. Lockyer to look at the sight, and we watched it till it was time to take position for observing totality. The lines were in view for nearly two minutes, during which time the cusp must have passed over more than 20° of arc, and the lines were only lost sight of when I moved the instrument, and placed the slit tangential to the point where the sun's light would disappear.

I then found the same bright lines in the field, and several others. One was noticeably bright. With a little difficulty I recognised this to be E, or exceedingly close to E; the ordinary solar spectrum being sufficiently strong to enable me to recognize the E group. The solar light was then

* *(Note by Capt. Tupman.)* Twenty-five minutes after the first contact the northern cusp was in the position N. 19½° W., the southern S. 40° W. Three minutes before totality the northern cusp was N. 42° E. Two minutes before totality it was N. 25° E. (Compare these positions with the prominences shown in Plates 7 and 8.)

very faint, and diminishing rapidly, whilst the number of bright lines increased till the spectrum was full of them. It seemed as if every dark solar line were reversed. They remained so an instant, and then vanished,—not instantly, but so quickly that it was impossible to note the order in which they disappeared. The hydrogen lines, near D, magnesium, and some other lines between D and *b*, remained till the last; then they vanished, and all was darkness.

Field of spectroscope full of bright lines.

Captain CHRISTIE then unclamped the instrument for me, and I moved in declination on each side of the moon,—darkness still.

I then went to the direct-vision spectroscope, but could see nothing. I pointed the telescope carefully to the corona, close to the moon, and swept out on both sides, but no light. I then carefully pointed the telescope to the centre of the dark moon, to repeat my observation of last year, but the light was not sufficient to penetrate. I saw nothing. . . . . The last 30 seconds of totality had arrived, and, according to previous arrangement, Mr. LOCKYER took my place at the 6-inch with eyepiece, and I went to the 6-prism spectroscope attached to the other tube, ready to note the spectrum of any point when required, but I saw nothing to note.*

Corona examined: nothing seen.

During the remainder of the eclipse, to the end, I watched the northern cusp, as uncovered by the moon, and for some time observed C, and the four lines near it, very distinctly. They were, however, very faint in comparison with C. After a little time the upper parts of all these five lines were displaced, to the violet side, about one and a half times the breadth of C. Two or three of the fainter lines were then visible as dark lines. The displacement was visible in all. The average height of all these was little more than the normal—about one-seventh of the height of spectrum.

On two successive nights before the eclipse, with the 6-inch refractor and direct-vision spectroscope of 7 prisms, I was able to see plainly three lines in the spectrum of the nebula in the sword-handle of Orion; and yet with the same instrument, during totality,† I was unable to detect any

Three lines in the spectrum of the nebula of Orion seen with the same instrument.

* On inquiry of Capt. MACLEAR, it appears that he swept in declination through the moon's centre to the right and left. This would have carried him into the areas of the great northern and southern rifts shown in the photographs; but it appears that he afterwards placed his spectroscope on what he judged to be the brightest part of the corona, but no light was visible.

† Capt. MACLEAR informs us that the same power was used on both occasions.

spectrum in any part of the corona,—though certainly I cannot say what width of slit I had in observing the nebula; but the lines were narrow and distinct. I do not think that the width of slit, when observing the nebula, could have been more than two or three times greater than when observing the corona. I formed this opinion from having had occasion to look at the slit occasionally, and from the width of the lines in the hydrogen tube used at the same time.

M. J. Janssen. 10° 27′ 8″ N. 76° 42′ 45″ E. SHOOLOR, INDIA, 12th Dec., 1871.

Rapport à l'Académie relatif a l'observation de l'éclipse du 12 Dec., 1871. (Extrait des "Annales de Chimie et de Physique," 1873.)

Instrument—A reflecting telescope of about fifteen inches aperture and very short focal length, equatorially mounted. Direct-vision spectroscope of ten prisms, with collimator and telescope adapted to take in the whole pencil. Slit about 10′ long.

1. Slit at about $\frac{2}{3}$rds. of a radius from the moon's limb—lines of hydrogen and 1474. On bringing the slit up towards the moon's limb the spectrum increased in brightness, but retained the same general constitution: at a distance of 3′ to 6′, the dark line D was observed, as well as dark lines in the green. 2. Slit placed radially so as to cut a prominence and lie partially upon the dark moon and corona. Spectrum from moon excessively faint; the principal lines from the protuberance prolonged themselves into the corona. 1474 seen in corona, but not in spectrum of prominence.

(p. 6.) Pendant l'éclipse de 1868, absorbé tout entier par l'analyse des protubérances, je n'avais point étudié la couronne; mais depuis, ayant beaucoup médité sur les observations de 1868, 1869, et 1870, j'étais arrivé à cette conviction, que la principale difficulté rencontrée dans l'analyse spectrale de la couronne devait provenir du manque d'intensité lumineuse. On sait, en effet, que nos spectres célestes dérivent d'un faisceau lumineux de $\frac{1}{10}$ à $\frac{1}{20}$ de millimètre de largeur, que le prisme étale sur une surface quelques centaines de fois plus considérable. Or, dans les lunettes ordinaires, l'image de la couronne est-elle assez vive pour supporter un tel affaiblissement et donner encore un spectre où l'œil puisse percevoir de délicates lacunes de lumière? L'affirmative paraissait bien douteuse, et je fus persuadé qu'il y avait là l'explication de plusieurs faits peu admissibles signalés par la plupart des observateurs en 1868, 1869, 1870, notamment la continuité du spectre coronal—résultat qui conduirait á admettre dans la couronne la présence de corps solides ou liquides incandescents.

Il n'était donc pas douteux pour moi que les spectres de la couronne, obtenus jusque-là, avaient été trop peu lumineux, pour qu'on pût en reconnaître la veritable nature, et cette conclusion sera admise par tous les practiciens qui savent combien la constitution apparente d'un spectre change, soit par excès, soit par défaut d'intensité lumineuse. La première

condition à réaliser était donc d'obtenir un spectre de la couronne suffisamment lumineux. J'eus alors la pensée de construire un télescope tout spécial, où les conditions optiques qu'un instrument de ce genre doit réunir seraient sacrifiées, dans une mesure admissible, pour tout reporter sur le pouvoir lumineux. Je reconnus, par un essai préalable, sur un miroir de 16 centimètres qu'on peut réduire la distance focale principale d'un miroir à n'être que le quadruple de son diamètre, et obtenir encore des images suffisamment pures pour l'objet que j'avais en vue. Or un miroir dont la distance focale est seulement quadruple de son diamètre donnera une image seize fois plus lumineuse* que celle d'une lunette astronomique de même ouverture, et qui aurait un foyer quatre fois plus long.

Janssen's observation, 1871.

Ce point fixé, je fis construire un miroir de 38 centimètres de diamètre qui prit un foyer de 1^m 42; le rapport de l'ouverture au foyer était encore un peu plus grands que celui de 1 à 4, et cependant, avec un bon choix d'oculaires, l'instrument montrait dans Jupiter des détails au delà des deux larges bands equatoriales bien connues. Mais il était un autre *desideratum* également important à mes yeux. On sait que dans les recherches d'analyse spectrale céleste on se trouve dans la necessité d'associer à la lunette qui porte le spectroscope une seconde lunette faisant fonction de chercheur pour diriger l'instrument analyseur sur le point qu'on veut étudier. De cette disposition résulte la necessité de deux observateurs:

Description of instrument.

* It will be seen that the efficiency of an instrument for spectroscopic purposes does not depend upon its focal length, for with a short-focused instrument a correspondingly short-focused collimator must be made use of; and although the image thrown upon the slit plate is more intense, the elementary portion of the image falling between the jaws of the slit will be correspondingly magnified. This will perhaps be more readily perceived if we consider the tele-spectroscope as compounded of two telescopes, one placed behind the other; the collimating lens being considered as the eyepiece of the front telescope. It will be seen that the shorter the focal length of the collimator the greater will be the magnifying power of the front telescope; and the power of the viewing telescope remaining unchanged, the greater will be the magnifying power of the whole combination. With a properly contrived collimator and viewing telescope the total power of the combination should be such that the whole pencil from the light-collecting object-glass or speculum just enters the pupil of the eye; but it is evident that this can be effected with equal facility whether the focal length of the light-collecting instrument is long or short. It will be seen also that no advantage will be gained by reason of the greater portion of the image which would fall between the jaws of a slit of given breadth with a short-focused instrument, for with a short collimator a proportionally narrower slit must be used in order to obtain a given degree of purity of spectrum.

In spite, however, of these considerations, the instrument made use of by M. Janssen should have given, by reason of its properly adapted collimator and telescope, a very brilliant spectrum.

Janssen's observation, 1871.

celui qui dirige le chercheur, et celui qui étudie les spectres. Il y a là un grand inconvénient. L'observateur qui étudie analytiquement les phénomènes d'une éclipse a le plus grand intérêt à les voir lui-même, et cela tant au point de vue de l'interpretation qu'il doit en donner que pour se guider dans le choix des points où devra porter son investigation.

Finder so placed that the observer at the spectroscope could use it without moving his head.

Il était donc très-important de trouver une combinaison optique qui permît à la même personne de remplir les deux rôles. Ce résultat fut obtenu par une disposition particulière du chercheur. L'oculaire de cet instrument fut muni d'abord d'un prisme à réflexion totale pour rendre la direction de visée parallèle à celle du spectroscope; ensuite l'axe optique de ce chercheur fut amené à une distance du spectroscope égale à celle qui sépare les centres pupillaires des yeux.

Cette disposition si simple permet alors d'aborder l'observation avec les deux yeux, et il suffit de fermer alternativement l'un ou l'autre pour obtenir, soit l'image de la région étudiée, soit le spectre correspondant.

J'ajouterai que ce chercheur était une excellente lunette, dont la distance focale avait été calculée de manière à obtenir dans le champ l'ensemble des phénomènes de l'éclipse. Elle portait une croisée de fils et un index au foyer commun de l'objectif et de l'oculaire. Quant au spectroscope, il était à vision directe, et construit sur le principe de celui que j'ai présenté a l'Académie dans la séance du 6 Octobre 1862, et qui est devenu le point de départ de tous les spectroscopes à vision directe, si usités aujourd'hui.

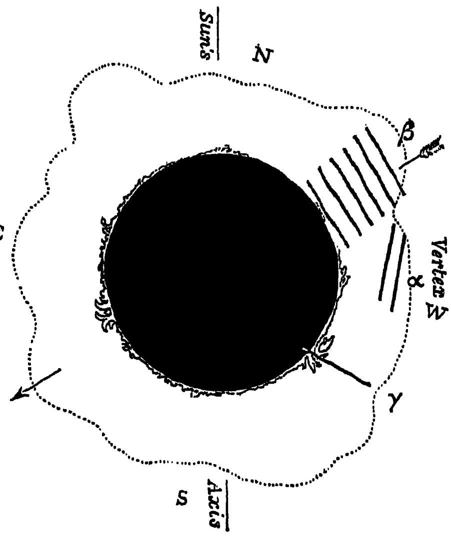


Diagram constructed to show the places of the slit during Janssen's observation.*

Prisms.

L'appareil dispersif de cet instrument était formé de deux prismes composés, comprenant chacun cinq prismes très-purs, réunis au baume de Canada. Je n'ai pas besoin d'ajouter que le foyer du collimateur fut mis en rapport de

* The outline of the corona is taken from the woodcut given in M. JANSSEN's "Rapport à l'Académie," published in the *Annales de Chimie et de Physique*, 1873. The places of the slit given in the diagram were marked by M. JANSSEN upon a copy of the above-mentioned wood-

foyer avec celui du miroir, de manière à profiter de toute la lumière donnée par celui-ci. Janssen's observation, 1871.

Ce spectroscope était si lumineux qu'il donnait le spectre des corps les moins éclairés de l'intérieur d'une chambre.* . . . .

(p. 19.) La totalité approchait. Le ciel était d'une admirable pureté. . . . . .

(p. 20.) Je reviens aux éléments lumineux du phénomène. Ma vue ayant encore toute sa sensibilité, je commence par l'examen du spectre des parties les plus hautes et les moins lumineuses de la couronne. Je place la fente du spectroscope à deux tiers de rayon† environ du bord lunaire. Le spectre se montre beaucoup plus vif que je ne m'y attendais à cette distance—résultat qui tient évidemment au grand pouvoir lumineux de l'instrument, et à l'ensemble des dispositions adoptées. Ce spectre n'est pas continu; j'y reconnais de suite les raies de l'hydrogène et la raie verte dite 1474: ‡ c'est un premier point très-important. Je déplace la fente en Description of observations.

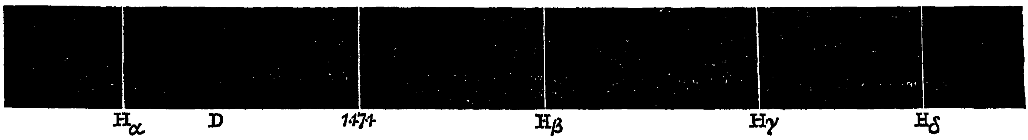


Diagram to illustrate the spectrum of the corona observed by Janssen.

restant toujours dans les hautes régions de la couronne: les spectres présentent toujours la même constitution.

cut. In answer to a letter asking how the picture was to be oriented, M. JANSSEN replied, "Sur le dessin la flèche indique seulement la direction du mouvement lunaire sans donner la ligne exacte des contacts. La figure doit être orientée d'après le Nord, qui indique le Pole céleste." The drawing has consequently been oriented from the north point, and the prominences would seem to indicate that the right orientation has been adopted. The question of the orientation is of some importance, since, if the arrow were taken as representing the direction of the moon's motion, the place of the slit marked γ would probably fall within the area of the great southern rift. The only prominence shown in the photographs towards the south pole is, as will be seen from plates 7 and 8, so placed that a line passing radially through it and extending outwards would fall within the area of the rift.

* It will be seen that M. JANSSEN did not succeed in observing the faint lines between D_3 and 1474. See the observations upon this subject at p. 365.

† In a letter received from M. JANSSEN in August 1873, giving information with regard to his observation, he writes: "J'ai constaté la raie 1474 dans toute l'étendue de la couronne visible, à 10′ ou 12′ en plusieurs points, mais n'ayant que 2 minutes, j'ai dû me borner à quelques points."

‡ *(Note by M. Janssen.)* Mon spectroscope portait une échelle très-précise; mais on va voir comment je me suis servi ensuite des raies mêmes d'une protubérance comme échelle.

[Ja]nssen's [ob]servation, [18]71.

Partant d'une de ces positions, je descends peu à peu vers la chromosphère, examinant très-attentivement les changements qui peuvent se produire. À mesure qui j'approche de la lune, les spectres prennent plus de vivacité et paraissent s'enricher, mais ils restent semblables à eux-mêmes comme constitution générale. Dans les hauteurs moyennes de la couronne, de 3 à 6 minutes d'arc, la raie obscure D se perçoit, ainsi que quelques lignes obscures dans le vert, mais celles-ci sont à la limite de visibilité. Cette observation prouve la présence, dans la couronne, de la lumière solaire réfléchie; mais on sent que cette lumière est noyée dans une émission lumineuse étrangère abondante.

[D]ark lines in [c]ontinuous [s]pectrum.

J'aborde alors l'observation très-importantes qui doit me donner les rapports spectraux entre la couronne et les protubérances. La fente est placée de manière à couper une portion de la lune, une protubérance et toute la hauteur de la couronne.

Faint spectrum from moon's disc

Le spectre de la lune est excessivement pâle; il parait dû principalement à l'illumination atmosphérique,* et donne une mesure précieuse de la faible part que notre atmosphère peut prendre dans le phénomène de la couronne. La protubérance donne un spectre très-riche et d'une grande intensité; je n'ai point le temps d'en faire une étude détaillée. Le point capital ici est de constater que les principales raies de la protubérance se prolongent dans toute la hauteur de la couronne, ce qui démontre péremptoirement l'existence de l'hydrogène dans celle-ci.

1474 seen in spectrum of corona, but not in spectrum of prominence.

La raie verte (dite 1474), si vive dans le spectre de la couronne, paraît s'interrompre dans le spectre de la protubérance; résultat très-remarquable. Je donne encore quelques instants pour bien constater la correspondance exacte des raies de la couronne, avec les principales raies de l'hydrogène dans les protubérances.

Capt. John Herschel.	11° 24′ N.	DODABETTA, near Ootacamund,
Col. J. F. Tennant.	76° 43′ E.	12th Dec., 1871.

Report by Lieut.-Col. J. F. TENNANT on observations made by order of the Government of India of the total eclipse of the sun on Dec. 11-12, 1871. *See also* "Memoirs R. A. S.," Vol. xlii., pp. 1—32.

Instrument—Two six-inch telescopes rigidly fixed together, and

* See the note on p. 359 with regard to the clear condition of the sky at Shoolor at the time of the total phase.

mounted on a stand with altitude and azimuth motion. One of the telescopes was used as a finder, and to the other was attached a recording spectroscope with one compound prism and a slit 18′ long. Herschel and Tennant's observation.

(p. 4.) I had asked Dr. HUGGINS to have two telescopes arranged, so that an observer using one in the usual manner should be able to place the slit of a spectroscope attached to the other on any object which he might desire to have examined. As I purposed moving the spectroscope during the short interval of totality from one object to another, and none of these probably would be very well defined, it seemed to me that an equatorial mounting with clockwork was not necessary, and I very much doubted if one could be got in the short time available. I had seen the efficiency of a wooden stand (somewhat similar in principle to what Dr. PEARSON describes as Varley's) employed by Dr. JANSSEN in 1868, and I looked to getting one of this sort quickly made and mounting on it two telescopes. By the kindness of the Astronomer Royal, however, Dr. HUGGINS was able to borrow for me one of the six-inch equatorial telescopes provided for the transit of Venus in 1874; and, in order to adapt this to my views, the counterpoise to the telescope was removed, and a second telescope of the same size placed at the other end of the declination axis. So modified, there was some difficulty in making it work as an equatorial, and it was resolved to let it be used as an alt-azimuth by placing the polar axis as nearly vertical as could be done without levels. . . . . Description of instrument.

I myself took the right-hand or guiding telescope, and the duty of selecting objects for examination; while Captain HERSCHEL took the spectroscope. . . . .

The second telescope was adapted to the use of the spectroscope which Dr. HUGGINS took to Oran, and which he has described. The Messrs. Grubb had provided for it a new compound prism, whose qualities are much the same as those of the most dispersive prism provided by them for the great Melbourne telescope. In this instrument there is a pointer which is visible without artificial illumination, except in a very dark field. It is traversed in the plane in which the image of the spectrum is formed by a coarse screw; and with it is moved the short end of a lever, of which the longer end carries two pricking points, one or both of which can be Description of spectroscope.

Herschel and Tennant's observation.

depressed by the action of a finger, so as to prick a record of the position of the pointer on a card; and allow of it being identified, and by its means that of any spectral line which was identical with it when the record was made. The eyepiece took in only a portion of the spectrum, along which it could be slipped by the hand, but there was no means of connecting it with the frame carrying the pointer. It will be seen then that, both hands being occupied, one in recording and one in moving the pointer, it became necessary to choose between the loss of time requisite to shift one hand to to the eyepiece and recover its position, and the abandonment of all but one portion of the spectrum. Captain HERSCHEL decided on the latter alternative, and confined his attention to the spectrum between B and F. The pointer which came out with the spectroscope only crossed about half the width of the spectrum, and could not without difficulty have been used with a narrow spectrum, except in the centre of the field; the solar lines, too, as seen in the spectroscope, were very markedly curved. Captain HERSCHEL therefore removed the pointer, and in lieu of it substituted a sewing needle: by bending this a little, and availing himself of the rounding of its point, he was able to secure a sufficient coincidence, across a large portion of the field, between a line of the spectrum and the edge of the needle nearest the less refrangible end of the spectrum, and thus avoid all corrections for curvature; but, on the other hand, this procedure could not but sacrifice some of the accuracy of which the instrument was capable, and this has helped to make some of the difference between different records of the same lines. Another small change was that, it having been found that the pricking point was prevented from marking in the middle of its traverse, at some of the settings of the card, additional positions for setting it were made, so as not to decrease the possible number of registers. The spectroscopic focus which had been obtained on the solar prominences was verified on the morning of December 10 (astromical) by a star, and the width of the slit was so adjusted as to show the principal dark lines of the spectrum of the sky near Sirius when it was fading out in the morning twilight. At this place the head of the adjusting screw of the slit was marked; and on the morning of the eclipse this mark was replaced at the position it had occupied the previous day, which can also be identified by its being three-quarters of a revolution from "shut." Captain HERSCHEL also states that b_2, b_3, and b_4 were not separate, nor were D_1 and D_2, but that

Herschel's observation, 1871.

apparently b_1 was separate from the other b lines, and D_3 from D; and this statement will probably give the best idea of the width of opening. The length of the slit was such as to give a spectrum some 18′ wide.

Just before the commencement of totality slit placed on southern cusp: numerous bright lines seen. After the commencement of totality, 1. Slit placed at moon's centre,—nothing visible; 2. Slit placed across the eastern edge of the southern rift,—one green line seen all across the field of the spectroscope, which was far from dark; 3. Slit placed about 8′ from the western limb, across a grey partition between bright rays,—spectrum precisely the same, except that both line and field were fainter; 4. Slit moved to about 16′ from western limb,—no lines seen, through faint light was visible in the field of the spectroscope; 5. Slit placed tangentially to the western limb at the end of totality,—the bright lines seen were so numerous that they could not be counted. After totality the green line was found to correspond with 1497 K.

The cusp which I placed in the field (as I have before mentioned) was that to my left, or the southern one, and on it Captain HERSCHEL verified the accuracy of accordance between the slit and the corresponding mark in the guide telescope. "While doing this," he says, "I noticed the usual three bright lines appearing as short projections on the right edge of the narrow strip of sun, spectrum becoming sensibly brighter, and very soon an additional spike or two appeared. I cannot recollect now *which* lines appeared first. But after a few seconds I felt impelled to make first a record; and, giving notice that I was about to do so, I pricked down rapidly all that I could feel sure of. By the time this was done, or very soon after, the number of short bright lines increased greatly, the strip of sunlight almost vanishing; another and wider series also appeared on the left. Just at the moment when (as I suppose) totality occurred, the appearance was, if I recollect rightly, that of a bright string of coloured *points*, or very short lines in the centre of the field, and of a *series of lines* on the left, extending where widest nearly up to the string—the distance from the centre to the centre being probably 3′ or 4′. But it is impossible to speak positively of the succession or simultaneity of appearances in a case like this, when there is reason to believe that the slit was being rapidly moved along in pursuit of

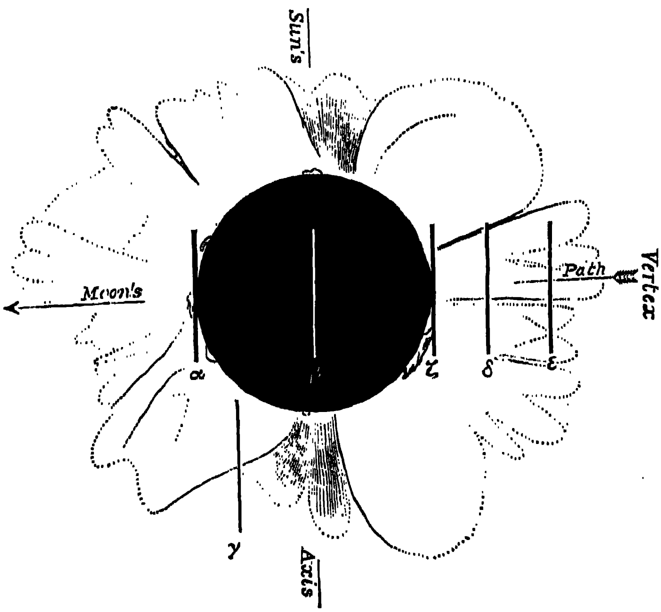


Diagram constructed to show the positions of the slit during Herschel's observation.*

* The outlines of the rifts and of the chief details of the corona are from the 1871 photographs.

a retiring cusp. Ultimately the spectrum presented was one of numerous, but not very many, bright lines, of various intensity and considerable length. I was told to record, and I did so: my impression is that I pricked all I could see, but there is no time to look about or pay much attention to anything but intersection, where a spectrum of nine or ten lines has to be seized in as many seconds."

It will be evident that Captain HERSCHEL had the spectra of both cusps of the chromosphere in the field.

Observations during totality.

As soon as this record had been completed at the place of the sun's disappearance, I turned the telescopes so as to place the slit on the centre of the moon. This had been particularly wished by Captain HERSCHEL, and I also was glad of an opportunity of seeing the whole outline of the moon, and getting a general view of the corona, that I might note any remarkably bright streamers, etc., for special examination. After a careful inspection Captain HERSCHEL reported nothing visible.

I then moved the slit to the nearly vertical edge* of a rift which was

1497

Diagram to illustrate the spectrum of the corona observed by Herschel.

1474 seen extending into the area of the southern rift.

very large and conspicuous to the apparent left of the moon, and placing it about 10′ from the limb, called on my companion to record. He says, "There was but one line in the field—of a green colour and pale, but extending all across the field; which I recollected, when I came to make notes, was far from dark, differing decidedly in this respect from that which I had just before searched."

The next point examined was about 8′ from the moon's limb, and apparently (in the inverting telescope) below the centre, the slit being entirely across a grey partition between the bright rays. This partition was nowhere dark, like the rift last looked at, but was much more marked than most of the grey portions of the spectrum. Captain HERSCHEL

* Col. TENNANT informs us that the slit was placed across the edge of the rift, so as to be partly upon the bright structure of the corona and partly within the rift. No sudden change in the intensity of the green line was observed at the part of the field corresponding to the edge of the rift.

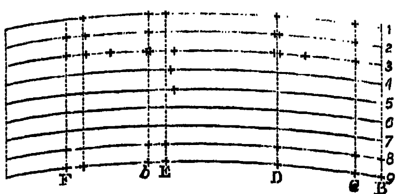
says: "The next record was precisely the same, except that both line and field were fainter. In both cases I was doubtful about recording traces of lines which I fancied I saw in various places, but it would have been hazardous to stop for them if they really were there. I have a distinct recollection of a dimly-illuminated field in which I could see the needle easily; and, when I reflect, I feel convinced that there must have been diffused light, due to the corona, of considerable intensity; for apart from the visibility of the needle, the comparatively feeble character of the single line seen is not in keeping with the brilliancy of the corona as apparent to the eye." Herschel's observation, 1871. 1474 and faint continuous spectrum seen at 8′ from W. limb.

I now moved the slit into another part of the same grey space, about double the last distance from the moon's limb. I still saw coronal light here, though it was faint. Captain HERSCHEL, however, could see no lines, though he saw faint light. Finally, I placed the slit where it was a tangent to the moon's limb, close to the place where the sun would reappear. The following is the account of the end of the eclipse here seen:— Faint continuous spectrum seen at 16′ from W. limb.

"Immediately, a number of bright lines, many of them already familiar, became apparent. I was about to attempt a final record, when the field began to brighten, not suddenly, but gradually, and immediately the number of lines increased so greatly that I could only look at them,—to record was hopeless. The gradual breaking in of the solar light was no doubt due to the slit being a little way off the limb." As a matter of fact, the slit was, as well as I could place it so, on the limb of the moon, and the brightening admits, I think, of another explanation. Bright lines too numerous to record.

I now proceed to the identification of the lines, in doing which I shall assume that in spectrum 3 (that taken at the first internal contact) C, D, D_3, b_1 and F were present, and correspond with marks on the register card. Identification of the lines.

From these points I proceed by interpolation.



True copy (same size as original) of the record on the register card.*

First comes a line between C and D, which I find would, if accurately noted, read 784 of Kirchhoff's

* Space No. 6 corresponds to the observation made at 16′ from the W. limb. A faint continuous spectrum was observed, but no bright lines were recorded. Space No. 7 corresponds

Herschel's observation, 1871.

scale. If this be one of the lines mentioned by Professor YOUNG in the Preliminary Catalogue (*American Journal*, November, 1871), then it must be No. 7 of his series; but it very closely corresponds to two strong lines in Kirchhoff's chart, and also to two iron lines 6392·5 and 6399 of Angström. The line between D and F is, I find, what would read 1497 of Kirchhoff. It is probably the known corona line 1474 K; but it may be worth noting that Professor HARKNESS obtained a line corresponding to K 1497 from several spectra of the chromosphere and prominences during the American eclipse of 1869. In Captain Herschel's corona spectrum No. 5, the noted line corresponds with this in No. 3, and in No. 4 it reads a little higher. Taking into consideration the faintness of the line, and the other sources of uncertainty which I have pointed out, there can, I think, be no doubt that all three are identical.

Near *b* is a line which is probably a combination of the magnesium lines b_2 and b_4.

Passing on towards F, we have a line whose place would be K 1849; this is probably 56 and 57 of Professor Newton's catalogue, corresponding with 1866·8, 1870·3 of Kirchhoff.

Still further on we have a line whose place reads as K 1988. It seems probable that this is 58 of the Preliminary Catalogue, or K 1989·5, a strong barium line in the solar spectrum, and one which Professor YOUNG seems to have seen somewhat frequently.

Colonel G. H. Saxton.

11° 24′ N. } DODABETTA, NEAR OOTACAMUND,
76° 43′ E. } 12th Dec., 1871.

Report by Lieut.-Col. J. F. TENNANT, on observations made by order of the Government of India of the Total Eclipse of the Sun on December 11-12, 1871. *See also* "Memoirs R. A. S.," Vol. xlii.

*Instrument**—Integrating spectroscope placed behind the eyepiece of a telescope, so as to receive parallel rays from a field of a little more than 50′ in diameter.

to the observation made when the slit was upon the W. limb at the end of totality. The bright lines were too numerous to record. The woodcut has been made from the plate given i Vol. xlii. of the "Memoirs of the R. A. S."

* The description of the instrument is by Captain HERSCHEL.

Saxton's observation.

C, D, and F seen at the beginning of totality: 1474 then appeared, and C, D, and F faded. Towards the end of totality C, D, and F re-appeared and 1474 faded. The cross-wires had been set to the position of K 1474 before totality, and they appeared to correspond exactly with the position of the bright line seen during totality.

(p. 19.) The Royal Society's equatorial was adapted as an integrator by inserting a double convex lens (1·8 inch in diameter), of $5\frac{1}{2}$ inches focus, into the spectroscope tube at about 2 inches beyond the slit, and then sliding the tube until the distance of this lens from the object-glass of the telescope was equal to the sum of the focal distances. Thus the slit received the rays from the object as the eye would receive them in like case, in parallel pencils; and could view (so to speak) just what the eye in its place could see. This was found to be a field of about 60′. The cotangent of half this (the radius of the field) is 115, and the magnifying power being inversely as the focal distances, or $62\frac{1}{4} \div 5\frac{1}{2} = 11\frac{1}{3}$ nearly, this field was presented to the slit under an angle of $2 \text{ cotan.}^{-1} \frac{115}{11\frac{1}{8}}$, or $2 \text{ cotan.}^{-1}\, 10 = 11° \, 24'$. But the collimating lens of the spectroscope subtends only an angle of 10°, consequently the outer portions of this field were not received through the centre of the slit; but, in part, through the ends. It seems the more necessary to go into this calculation, as the integrating spectroscope has not been so minutely described hitherto as to put its essential features beyond doubt. The principal of these seem to be, that every part of the area whose light is to be integrated shall—or should, if the slit were a pin-hole only—throw its slitful or pinholeful of rays on to the collimating lens. This would be perfectly effected without any lenses in front of the slit; but the area gathered from would then be needlessly large, so that a magnifying power sufficient to increase the desired area to that which the collimating lens can receive, is requisite. But given the desired area, and the aperture of the lens, and consequently the power required, it is not clear that there is advantage in using a larger telescope.

If this conclusion be correct, the failure of the integrating spectroscope on this occasion is accounted for. If not, the cause must be sought in the undoubted fogging of the prism, and the narrowness of the slit.

All the adjustments were performed by Captain Herschel during the hour preceding the eclipse. The clockwork, adjusted to solar motion, kept the telescope directed to the sun's centre. The slit was opened to the extent necessary to run the two upper *b* lines into one band, and the eye-telescope was suited to the observer.

The following report was written down [by Col. Saxton] while standing at the instrument after totality:—

Observation.

"The dark lines C, D, and F, at totality changed suddenly into bright lines. K 1474 did not appear for some time; and when, or before it did, C, D, and F had faded away. It remained for a short time only; and then, just before the light returned, C, D, and F again for a moment became bright before changing to dark lines."

1474

Diagram to illustrate the spectrum* observed during totality by Saxton. The bright lines C, D, and F, were also observed at the beginning and end of totality.

A note was afterwards added explaining the use of the letter D, and the statement about its inversion, as recognised inaccuracies. Colonel Saxton also adds that the "dark lines before and after totality were numerous and distinct, the principal ones well marked. . . . . Throughout the observations, with dark as well as light field, the cross-wires were easily seen, but he did not notice any trace of any bright line except the above. . . . . The cross-wires, which had been carefully placed in the position due to K 1474, appeared to intersect that bright line truly."

Prof. L. Respighi.

10° 25′ N. } Poodocottah,
79° 15′ E. } 12th Dec., 1871.

"Nature," Vol. v., pp. 237-8.

Instrument—A flint-glass prism of small angle, placed in front of the object-glass of a $4\frac{1}{2}$-inch refracting telescope.

A few seconds before totality the spectrum became continuous. The reversal of the lines was not seen, though it appears to have been seen at the end of totality. Just after the commencement of totality, and just before the end, images of the chromosphere observed corresponding to

Preceding observations having shown that the light of the solar corona is composed for the most part of a small number of elementary rays differing considerably in refrangibility, it appeared to me that the form and dimensions of the higher chromosphere might be conveniently studied by means of a large prism fixed in front of the object-glass of the telescope, whereby the several chromatic images of the corona would be distinctly formed in the focal plane. If the prism has but little dispersive power, and the eyepiece does not magnify too much, all the chromatic images of the

* On p. 21 Col. Tennant says, in referring to Col. Saxton's observations, "There is nothing positive but the (apparently) continuous spectrum, and the single coronal line."

corona may in this manner be observed simultaneously in the same field, and their form and dimensions directly investigated.

the rays C, D_3, F, and G. During totality spectral images of the corona observed corresponding to C, 1474, and F. The green zone was the brightest and the most uniform; the red zone was also distinct; and the blue the faintest. The green and red zones extended to a height of about 6′ or 7′.]

Towards the end of the year 1868, a small flint-glass prism was made for me by Signor Merz, of Monaco, to be fitted to the object-glass of the equatorial belonging to the Observatory of Campodoglio, for observations on the spectra of the stars; and this apparatus, in consequence of the dispersion of the prism, and the goodness of this prism and of the object-glass, was found to be admirably adapted for observing the eclipse in the manner just described.

The dispersion of the prism, from the lines C to H of Fraunhofer, is about 32′; the free aperture of the object-glass is $4\frac{1}{3}$ French inches; the field of the telescope is about 1°, with a magnifying power of 40. . . . . On the morning of the 12th, the sky was almost wholly covered with dense masses of mist and cloud, completely obscuring the sun till 7 h. 53 m., at which time the eclipse had already begun. Soon after this the sun was again covered with thick clouds; but fortunately they began to break* a few minutes before totality, when the bright disc of the sun was already sufficiently reduced and when consequently the time for observation was rapidly approaching.

To verify the phenomenon of the reversal of the spectral lines at the extreme edge of the sun, I had arranged the plane of dispersion at right-angles to the edge at the point of second contact.

At thirty seconds before totality, the spectral image of the luminous crescent was already sufficiently weakened to allow of its observation by the naked eye without a dark glass; and it was then that the principal dark lines of the solar spectrum came out distinct, and even more strongly marked than before, and curved parallel to the bright edge of the sun; but a few seconds before totality these lines disappeared completely, and the spectrum became continuous—without, however, exhibiting just before totality the reversal of the lines, although I was watching most intently for this phenomenon. I would not, however, be understood as denying

* In his Italian account of his observations, published in the "Atti della Reale Accademia de' Lincei" for March 3rd, 1872, at p. 14, Prof. Respighi says: "Fortunamente però alcuni minuti prima della totalità fummo quasi inaspettatamente rallegrati dalla vista del sole, gia ridotto ad un sottile crescente, ad una sottile falce luminosa; e diradandosi ognora più la nebbia e le nubi, ad un minuto circa prima della totalità esso appariva abbastanza chiaro e limpido; e cominciarono allora le mie osservazioni."

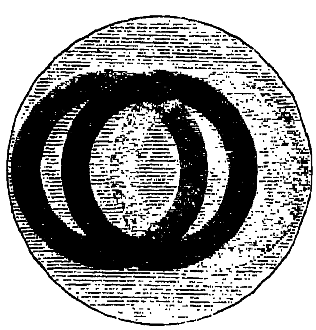
Respighi's observation.

altogether the reversal of the lines, for it is not impossible that a thin film of mist, or the bright atmospheric light at that time diffused over the spectrum of the solar limb, may have concealed the bright lines.

Spectral images of the chromosphere.

At the very instant of totality, the field of the telescope exhibited a most astonishing spectacle. The chromosphere at the edge, which was the last to be eclipsed—surmounted for a space of about 50° by two groups of prominences, one on the right, the other on the left, of the point of contact—was reproduced in the four spectral lines, C, D_3, F, and G, with extraordinary intensity of light and the most surprising contrast of the brightest colours, so that the four spectral images could be directly compared and their minutest differences easily made out.

In consequence of the achromatism of the object-glass, all these images were well defined, and projected in certain coloured zones, with the tints of the chromatic images of the corona. My attention was mainly directed to the comparison of the forms of the prominences on the four spectral lines, and I was able to determine that the fundamental form, the skeleton or trunk, and the principal branches, were faithfully reproduced or indicated in the images; their extent being, however, greatest in the red, and diminishing successively in the other colours down to the line G, on which the trunk alone was reproduced.



Zones * observed by Respighi.

In none of the prominences thus compared was I able to distinguish, in the yellow image D_3, parts or branches not contained in the red image C.

Images of the corona.

Meanwhile the coloured zones of the corona became continually more strongly marked: one in the red corresponding with the line C, another in the green probably coinciding with the 1474 of Kirchhoff's scale, and a third in the blue perhaps coinciding with F.†

* The diagram does not sufficiently show the difference in brightness between the three zones. In the plate accompanying Prof. RESPIGHI's Italian account of his observations, published in the "Atti Accademia," the three zones are given as perfectly uniform rings sharply defined at their summits, and without any trace of structure or rifts. The 1474 zone is given as much brighter than the C and F zones.

† In a letter describing his observations, addressed by Prof. RESPIGHI to the Organizing Committee of the 1871 Eclipse Expedition, he says:—

"Je ne puis distinguer que trois zones colorées: une dans le rouge, en coincidence avec la

The green zone surrounding the disc of the moon was the brightest, the most uniform, and the best defined; the red zone was also very distinct and well defined; while the blue zone was faint and indistinct. The green zone was well defined at the summit, though less bright than at the base; its form was sensibly circular, and its height about 6′ or 7′. The red zone exhibited the same form and approximately the same height as the green, but its light was weaker and less uniform. The height of the green zone was estimated by comparison with the moon's diameter, Respighi's observation

raie C; une dans la verte, probablement en coincidence avec la raie 1474 de Kirchhoff; et le troisième dans le bleu, probablement en coincidence avec la raie F. Et s'il y avait d'autre images, leur éclat devait être si faible, qu'il ne pouvait se distinguer de l'éclat général du champ. . . . .

"Des trois zones ou images de la couronne visible dans ma lunette, la plus lumineuse et la mieux definée au sommet était la verte: la rouge, quoique suffisamment definie, était beaucoup moins lumineuse, et moins uniforme dans son éclat: la zone bleue était assez faible et d'une forme indécise.

"La zone verte présentait nettement la forme d'un anneau sensiblement circulaire: son éclat allait régulièrement en diminuant avec la hauteur, sans présentant néanmoins une différence trop marquée entre la partie plus basse sur le disque lunaire et la sommet. La hauteur ou l'épaisseur de cet anneau, je l'ai jugée, comprise entre 6′ et 7′—c'est-à-dire, de plus de 20 diamètres terrestres.

"La zone rouge présentait la même apparence, et à-peu-près la même hauteur, mais son éclat était moins intense et moins uniforme que celui de la zone verte, de sorte que dans les parties superposées se détachait bien décisivement le contour de cette dernière.

"La zone bleu était très-faible et indécise, et dans les régions supérieures elle devenait invisible, peut-être même à cause du contraste de la lumière intense de la zone verte.

"Dans les parties superposées de ces anneaux—c'est-à-dire, dans les arcs proches au diamètre perpendiculaire au plan de dispersion du prisme—la lumière diffuse était très intense, pas assez cependant pour voiler la contour supérieur de la zone verte. . . . .

"Par ces observations il me semble incontestablement démontré que—

"(1) Au dessus de la couche rose ou de la chromosphère, il existe une autre enveloppe gazeuse et incandescente, formé principalement de la substance inconnue qui donne la raie verte 1474 de Kirchhoff et d'hydrogène.

"(2) Cette masse gazeuse est distribuée autour du soleil avec une apparente uniformité et avec une faible densité décroissante apparemment de bas en haut.

"(3) La hauteur de cette enveloppe gazeuse est approximativement comprise entre 6′ et 7′, par conséquant pas moindre que 20 diamètres terrestres.

"(4) Cette enveloppe gazeuse, malgré sa grande rarefaction, est bien définie à son sommet, et limité par une surface approximativement sphérique.

"(5) Dans cette couche gazeuse il n'y a aucune trace de la structure radiale des jets et des panaches présenté par la couronne à l'œil nu, ou dans les lunettes, ou dans les images photographiques."

Respighi's observation.

and from the observed distance of the spectral lines of the prominences.

These coloured zones shone out upon a faintly illuminated ground, without any marked trace of colour. If the corona contained rays of any other kind, their intensity must have been so feeble that they were merged in the general illumination of the field.

Images of chromosphere on western limb.

Soon after the middle of the total eclipse, there appeared on the western limb, at about 110° from the north point, a fine group of prominences, formed of jets rather low but very bright: some rectilinear, others curved round the sun's limb, and exhibiting the intricate deviations and all the characters of prominences in the neighbourhood of solar spots. The brightness and colour of these jets were so vivid as to give them the appearance of fireworks.

The spaces between some of these jets were perfectly dark, so that the red zone of the corona appeared to be entirely wanting there. Perhaps, however, this was only an effect of contrast due to the extraordinary brightness of the neighbouring jets. I have thought it right to refer to this peculiarity, because the appearance of interstices, or dark spaces, between prominences of considerable brightness, is often observed by means of the spectroscope, independently of total eclipses.

The want of an assistant to note the time, and to write down the observations as they were made, occasioned me some loss of time, and the end of the total eclipse was already at hand before I was aware of it.

The green and red zones were well developed at the western as at the eastern limb, while the blue remained faint and ill-defined.

End of totality. Bright lines.

Soon after the appearance of the chromosphere at the western edge, there was suddenly projected on the spectrum of the sun's limb, which then appeared beyond that of the moon, a stratum * of bright lines, sepa-

* At p. 21 of his paper in the "Atti Accademia," Prof. RESPIGHI says, "Mentre stava esaminando l' indicato gruppo di protuberanze [*i. e.*, the great group of prominences at about 240° to 250°, see plates 7 and 8] ed alcuni altri che andavano spuntando dal bordo lunare, e insieme le immagini cromatriche della corona principalmente nel bordo occidentale, apparsa la cromosfera, piuttosto bassa in quella località, vidi projettarsi quasi istantaneamente sullo spettro uno strato di righe lucidissime.

"Portai immediatamente la mia attenzione su questo sorprendente fenomeno per verificare, se si trattase di un rovesciamento generale o parziale delle righe dello spettro solare, ma troppo presto un torrente di viva luce riversandosi sullo spettro, sommergeva quelle righe lucide in uno

rated by dark spaces; but I could not determine whether they were due to a general or partial reversal of the spectral solar lines, or to a simple discontinuity in the spectrum, since they were too soon immersed in a flood of light, which put an end to the totality of the eclipse.

Capt. A. B. Fyers, R.E. 9° 43′ N. 80° 10′ E. JAFFNA, 12th Dec., 1871.

MS. Reports of the 1871 Eclipse Expedition.

Instrument—An integrating recording spectroscope, with one prism of 60°.

I observed with an integrating spectroscope, having one large prism of 60° and a collimating telescope of about 1⅓ inch aperture and 22 inches focal length. The telescope carried a recording apparatus, consisting of a needle-point attached to a rack, and driven by a pinion or mill-screw. The needle was placed in the common focus of the object-glass and positive eyepiece. It travelled up and down the spectrum, so as to coincide at will with any line.

Instrument used by Capt. Fyers.*

Just before totality the Fraunhofer lines suddenly changed to intense brilliancy, resembling sparkling threads. Their brightness lasted for 1½ or 2 seconds; they then disappeared suddenly, leaving four bright lines in a dark field. The positions of these four lines were pricked off three times in succession: they agree very nearly with C, D, 1474, and F. No lines could be de.ected beyond F.

spettro continuo, sul quale spiccavano alcune masse di luce rossiccia, costituite dalle immagini C delle protuberanze, fra le quali si rimarcava principalmente quella de un gruppo di protuberanze vicino al punto Nord, la quale si mantenne visibile per varii minuti dopo la fine della totalità; e con ciò finirono le mie osservazioni dell' eclisse totale. L' apparizione dello strato di righe lucide era certamente il fenomeno osservato da YOUNG e dal NOBILE di Napoli nell' eclisse dell 1870; ma non saprei decidere in base alla mia sola osservazione, se tale fenomeno fosse proprio di tutto il bordo solare, o non piuttosto parziale e dipendente dalle locali, ed anormali condizioni nelle quali trovavasi, il bordo solare nella località del contatto, ove aveva termine l' eclisse totale."

If the reversing stratum at the base of the chromosphere is very shallow, it is evident that an arc of only a few degrees along the lunar limb would be exposed before the first burst of photospheric light would put an end to the observation; and the fact that RESPIGHI only observed a band of bright lines (strato di righe lucide) in the midst of the broader spectrum of the chromosphere and corona, must not therefore be taken as indicating that the phenomenon was due to a local irruption.

With reference to the question which naturally suggests itself as to the reason why a similar bright-line spectrum was not seen at the commencement of totality, see the remarks on p. 337, and the note on pp. 337-8.

* We are indebted to Capt. TUPMAN for the drawing of this instrument.

Fyers' observation.

The needle was connected with the shorter arm of a lever, at the other end of which were two spring prickers, moving in the arc of a circle over a copper plate, rigidly attached to the telescope body. The dispersion of the prism as represented on the copper plate was small, the distance from C to G being about two inches.

The spectroscope was very solidly mounted equatorially, and driven by clockwork. . . . .

(p. 9.) Between 7.15 and 7.30 a.m., on the morning of the eclipse, I marked off very carefully on the copper recording-plate five separate reference lines as follows, the numbers being Kirchhoff's,—*viz.*, 593 (B), 694 (C), 1005 (D), 1464, 1523 (E), 1655 (*b* lowest line of the three), 2080 (F), 2308, 2722, 2855 (G).

Bright-line spectrum.

(p. 10.) At about 7 h. 48 m. 10 s., or just as totality commenced, I fixed my eyes steadily on the solar spectrum. The dark lines suddenly changed to intense brilliancy, resembling bright, sparkling threads. At the same time, the prismatic colours of the spectrum became intensified* and distinctly defined. The spectrum then became almost black, but with the colours still traceable. . . . . Their brightness only lasted

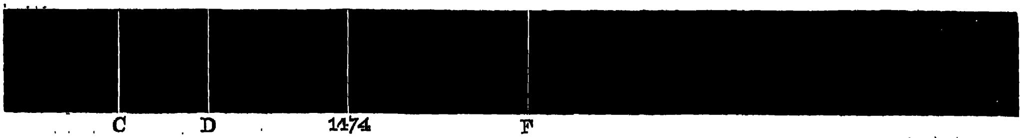


Diagram to illustrate the spectrum observed by Fyers.

for about a second and a half, or two seconds, when they disappeared suddenly, and four bright lines only remained in the dark spectrum. The slit of my spectroscope had then to be opened, in order that the lines might be more distinctly seen. . . . .

(p. 11.) I pricked off carefully each side of each bright line, except 694 (C), of which the side nearer D only was marked. I was able to prick off each line about three times; their positions agreeing nearly with 694 (C), 1005 (D), 1474, and 2080 (F). Unfortunately, there was a certain amount of parallax in the instrument which could not be corrected; some of the dots appear consequently a little out of position.† . . .

* "Colours intensified." This most probably means became more striking, as seen as disconnected threads upon a black background.

(*Note by Capt. Tupman.*) The lines pricked off on the copper plate during totality,

Just as I had pricked the position of the lines visible during totality for the third time, the solar spectrum with its black lines suddenly re-appeared. Fyers' observation.

I subsequently pricked off five times the same reference lines as I had marked before totality, in order that a thorough comparison might be made between them and the corona lines.

I examined the blue and violet end of the spectrum during totality, but could detect no lines beyond 2080 (F).

Capt. Tupman. 9° 40′ N. } JAFFNA,
79° 59′ E. } 12th Dec., 1871.

MS. Reports of the 1871 Eclipse Expedition.

Instrument—By the side of the finder was attached one of Browning's five-prism direct-vision spectroscopes, similar to the one used by Mr. MOSELEY.

(p. 11.) During totality I took one glance into the spectroscope, the 1474 seen, together with several other extremely faint lines between C and F.

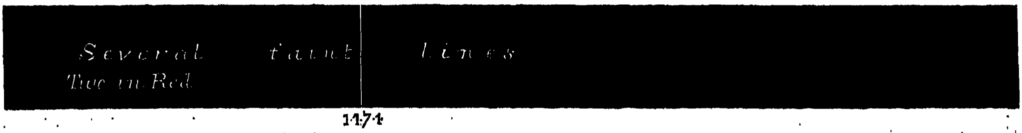


Diagram to illustrate the spectrum observed by Tupman.

slit of which was sufficiently fine to divide the sodium lines in the solar spectrum, and was adjusted so that the C and F lines were within the field. I saw one bright green line, which I knew to be 1474, and several others extremely faint * between C and F, of which I think two were in the red.

although agreeing fairly *inter se*, are very far from coinciding with the corresponding solar lines, pricked off just before and after totality on either side of the plate. All four lines were displaced towards the red end to the extent of about 50 (?) divisions of Kirchhoff. After the eclipse the spectrum of sodium was pricked off on another plate, and with reference to the solar D was similarly displaced.

* (*Note by Capt. Tupman.*) The extreme faintness of the hydrogen lines is fully accounted for by the narrowness of the slit.

Mr. A. W. Ferguson.

9° 12′ N. } PULMOTTE, N.E. coast of Ceylon,
80° 50′ E. } 12th Dec., 1871.

MS. Reports of the 1871 Expedition.

Instrument—An integrating spectroscope, mounted equatorially with clockwork, one prism of 60°, and long collimator, with object-glass, of such aperture that an angle of about 3° could be taken in. The instrument was similar to that used by Capt. FYERS, except that it had no recording apparatus.

The positions of the lines are given by estimation. For a few seconds after totality all was dark, then F suddenly appeared very bright. About five seconds later three more lines, which were calculated to be 1474, D, and a dark-red line estimated as *a*. About the middle of totality a line slightly more refrangible than 1474 was observed rapidly appearing and disappearing, and towards the end of totality three green lines between D and 1474. No continuous spectrum was detected.

On the voyage out from England, on board the *Mirzapore*, I had a few opportunities of making myself acquainted with the use of the Dublin spectroscope, and accordingly it was decided that that instrument should represent the sphere of my labours. Daily application during the week preceding the eclipse made me thoroughly master of the position of the principal lines in the solar spectrum; consequently, notwithstanding the failure of the reference spectrum at the critical moment of totality, I was able to give with pretty considerable accuracy the position of the bright lines I then saw. These were the following, in the order in which they appeared to me. For a few seconds after totality commenced, all was dark; then F suddenly appeared very bright, and continued of the same intensity till totality was over; about five seconds later, three more lines appeared in the field, which I calculated to be 1474 (an exceedingly brilliant line), D (or a line near D), and a dark-red line so far towards the red end of the spectrum that I called it *a*; I do not think it could possibly have coincided with C.

About the middle of totality a line slightly more refrangible than 1474 caught my attention by its flickering nature, rapidly appearing and disappearing. Just before the end of totality, three green lines flashed in between D (or near D), and 1474, their positions respectively being about $\frac{1}{8}$th, $\frac{1}{4}$th, and $\frac{5}{8}$th of the distance between these two lines, counting from D (or near D).

I therefore saw in all eight lines; and reckoning the intensity of 1474 as 6, I should ascribe to the rest the following numbers;—

Ferguson's observation.

a (= C?)	4
D (or near D)	4
$\frac{1}{8}$th between D and 1474	3
$\frac{1}{4}$th between D and 1474	3
$\frac{5}{8}$ths between D and 1474	1
1474	6
The line slightly more refrangible than 1474	3
F	5

I saw no continuous spectrum, and no dark lines. The following is a map noting the position of the eight lines I saw.

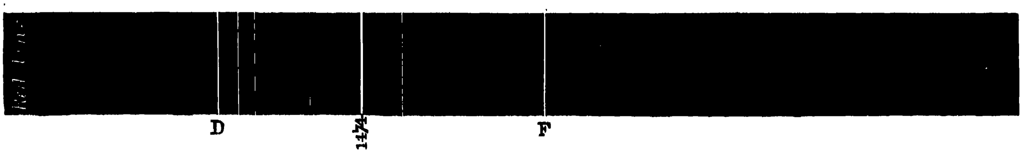


Diagram to illustrate the spectrum observed by Ferguson.

Mr. H. N. Moseley.

9° 12′ N. } 80° 50′ E. } PULMOTTE, about 40 miles N. of Trincomalee, 12th Dec., 1871.

MS. Reports of the 1871 Expedition.

Instrument—Refracting telescope by Dolland, of $3\frac{1}{2}$ inches aperture and 33 inches focal length, mounted on an unsteady stand. A sextant telescope was attached by a wooden bracket, to serve as a finder. Fixed to the $3\frac{1}{2}$-inch telescope was a direct-vision spectroscope* of five prisms, its slit subtended an angle of about 13′, at the focal distance of the object-glass.

The slit was set tangential to the east limb. At the commencement of totality, the solar spectrum disappeared, leaving F bright on a dark field; then D3, C, and 1474 were seen,

The spectroscope was one in which, in order to bring into view successive portions of the spectrum, it was necessary to move the slit (the slit-plate being for that purpose moved in a slot). I found that when the spectroscope was so adjusted as to bring the C and F lines at the same time well into the field of view—the position which I considered most

* (*Note by Capt. Tupman.*) MOSELEY used a direct-vision spectroscope by Browning, with 2 flint and 3 crown prisms. Collimator 5 in. focal length, 0·7 in. aperture. Examining telescope 6 in. focal length and 0·7 in. aperture. Ordinary negative eyepiece. Power of the whole combination about 40.

and lastly two green lines between 1474 and D flashed in and disappeared. No reversion of the dark absorption lines was observed, although it was especially watched for. After about ten seconds the slit was moved to the moon's centre, but no spectrum was seen; then to a portion of the corona, about 22′ from the limb, where the line 1474 was observed.

favourable for eclipse observation—the centre of the slit was far from coinciding with the axis of the telescope. . . . . I could not therefore rotate my spectroscope, as this would have rendered the finder useless. I therefore, just before the eclipse commenced, placed the slit tangential, or rather roughly at right-angles to the line of motion of the moon's centre, in order that I might have it tangential to the last remnant of the sun's limb at totality. . . . .

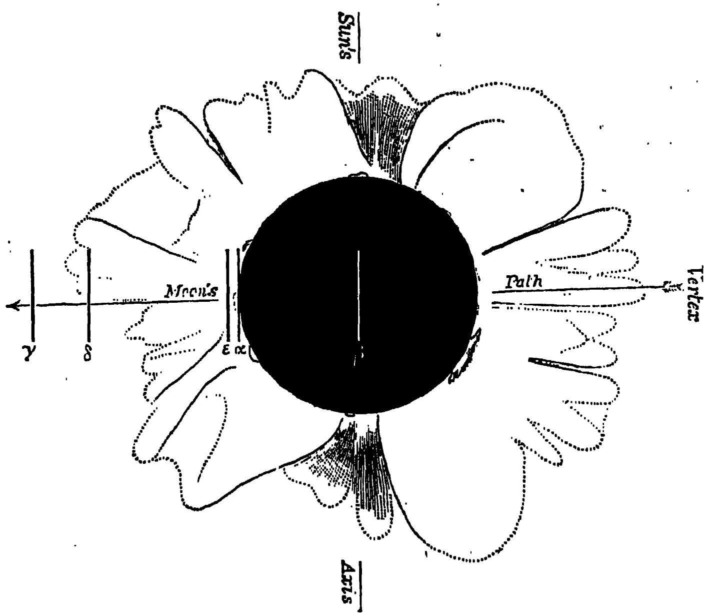


Diagram constructed to show the places of the slit during Moseley's observation.

(p. 6.) [When the remaining crescent was quite thin,] the field of view of my instrument was occupied by a central streak of bright light, brighter along its middle than at its edges, showing the principal dark lines of the solar spectrum, and on each side of the streak by a much fainter solar spectrum. Immediately before totality the central streak appeared to break up into several smaller streaks separated by dark bands; this appearance being due, I suppose, to Baily's beads. The next thing I saw was the F line bright, in an otherwise perfectly dark field. It appeared to grow rapidly brighter, as if by flashes of increased intensity at definite intervals.* Perhaps

* We would suggest that this appearance may have been due to vibration of the telescope, as the slit was brought up to the east limb. Mr. MOSELEY mentions that his stand was very unsteady, and that he did not touch his telescope until he moved his slit to the moon's centre. It will be seen that if the telescope had remained fixed, the diurnal motion of the sun would have carried the slit away from the east limb; but if we assume that the telescope was badly balanced, and that the eye end weighted with the spectroscope was slowly slipping downwards, it will be seen that the slit would be carried upwards or towards the west limb upon the image of the corona. This may possibly account for the order in which the lines were observed. 1474, which appeared last, would probably, in the region of the chromosphere, be less bright than C, D_3, and F. See the remarks on p. 368, with regard to the relative brightness of the

half a second passed before I saw another line,—and this was a yellow one, I believe D_3, followed instantly by C, which, like F, brightened rapidly, and then (F, D_3 and C being still bright) appeared what must have been from its position and colour 1474, which flashed out apparently brighter than any of the other lines, and then seemed to grow duller. I saw no faint continuous spectrum between the bright lines. The background appeared to me to be quite dark. Moseley's observation.

At the moment of totality I watched carefully for a reversal of all the lines of the spectrum; as it has been suggested that the sudden reversal of all the lines at the instant of totality does not really occur, but that observers seeing the sudden appearance of the various bright lines of the chromosphere and prominences in the field of view, imagine that they have seen all the lines reversed. I paid particular attention to the line E,* and a line about half-way between D and E, since these lines are not, as far as I know, either chromosphere or prominence lines. I requested Mr. Ferguson to watch the same lines in his spectroscope, but neither of us saw any sudden reversion of all the lines.

From just before the time when I saw the streaky appearance in my spectrum until now, I had not placed my hand to the telescope, because of the embarrassing vibration which this produced. The slit had thus by the rotation of the earth gradually moved away from the limb of the dark moon; and this circumstance may have had something to do with the order

1474
(probably)

Diagram to illustrate the spectrum of the corona observed by Moseley.

in which the lines appeared to me. Just before I altered the position of my instrument, I saw two faint green lines, close together, flash in between the 1474 and D, and then disappear.

It must be remembered that in order to get a field of view extending from C to F, and to lose as little light as possible, I used a very low-power eyepiece—far lower than the one which I used to observe the pro-

1474 line and the C and F lines in the spectrum of the corona, and in the spectrum of the chromosphere.

* Both the E lines have since been seen reversed in the spectrum of the corona. See Young's "Catalogue of Chromosphere Lines," published in 1872.

Moseley's observation.

minence spectrum before the eclipse. With this eyepiece I was just able to see on favourable parts of the sun's limb before the eclipse, where there was a large prominence, C and D_3 as very short and bright lines, but I was unable to see anything of the chromosphere with it.

Hence, if the region round the sun from which the light is emitted, which gives a reversal of all the dark lines during an eclipse, be very narrow indeed, it is possible that my instrument may not have had sufficient analysing power to show it.

After totality had lasted about ten seconds, I placed the slit of my spectroscope, by means of the finder, on the dark moon's centre, but got no spectrum whatever. I then depressed the telescope, and placed it on a very distant part of the corona, at a great distance from the sun's limb—perhaps thirty minutes or more—but still where the light of the corona was plainly visible through the finder; but no spectrum was to be seen.

I then moved the slit back again on to the dark moon, with the same result as before. I then placed the slit on the corona again in the same direction as before, still tangential to the sun's limb, and got the line 1474.

1474 seen at 22′ from the limb.

On the table beside me was a sketch of the cross-wires of my finder, and I hurriedly made a pencil mark on this, showing as nearly as possible the position of the sun's limb in the finder. On consulting this diagram afterwards, I found the distance of the slit from the sun's limb to have been about 22′. Of course this determination is very rough, and certainly not to be relied on within 5′. As I did this, the sun began to reappear. I then thought I would take a last look, with the slit tangential to the sun's limb, opposite to where the sun was reappearing. I was surprised to see 1474 still bright, and I watched it for nearly half a minute, till it disappeared.

Mr. N. R. Pogson. 13° 8′ N. } MADRAS, 80° 20′ E. } 6th June, 1872.

" Monthly Notices," Vol. xxxii., p. 331.

Annular eclipse. Bright lines seen at first internal contact, and again at the breaking up of the annulus. They lasted for some

At the first internal contact (just after a peep in the finder had shown me the moon's limb lighted up by the corona) I saw all the dark lines reversed and bright, but for less than two seconds; the thinnest thread of sunlight restored them instantly. . . . .

The sight of beauty, above all, was however the reversion of the lines at the breaking up of the limb. *All* lighted up—reminding me of the platinum wire in the Oxford heliometer, seen through the object-glass some distance off, when Mr. JOHNSON was putting on the battery to read the scale. The duration astonished me—five to seven seconds; and they faded out gradually, not momentarily. I had even time to turn the micrometer cross-wires upon the most brilliant line of all, which I took for C at the moment, but which the reading clearly showed was B * when all was over.

5 or 7 seconds' and faded out gradually.

Mr. Stone.

29° 14′ S. } KLIPFONTEIN,
17° 40′ E. } 16th April, 1874.

"Memoirs of the Royal Astronomical Society," Vol. xlii.

Instrument—A four-inch telescope, mounted on a tripod stand, with horizontal and vertical motions, and provided with a small finder-telescope. *Spectroscope*—a Browning star-spectroscope, with two dense flint-prisms of 60°.

(p. 43.) As the time of totality approached, I rested my eye for some time. The diminishing segment of the sun's disc was then brought into the centre of the slit, and carefully kept there until the instant of totality. At that instant, and for some little time afterwards, the field appeared to be full of bright lines of very different lengths. My impression was that all the Fraunhofer lines were seen reversed; but this is, of course, only an impression. I can only state as a matter of fact that a very large number indeed of bright lines were seen. I had hardly recovered from the surprise at the sight presented, and begun to attempt to count the lines, when the greater portion of them vanished, and I saw little more than a hydrogen spectrum. It is difficult for me to form any correct idea of the time during which the general reversion—or what I assumed to be the general reversion—of the Fraunhofer lines lasted; but I should hardly consider that it could have been longer than a second. From the shortness of many of the lines it would have been quite impossible to have seen their reversion unless the slit had been very perfectly adjusted parallel to the

The slit was placed tangentially to the E limb. At the instant of totality and for about a second after, the field of the spectroscope was seen to be full of bright lines of very different lengths. These vanished, and the slit was swept across the inner corona. The hydrogen lines, a green line, and two, possibly three, much fainter less refrangible lines were seen all across the field. In the spectrum of the outer corona there was but one bright line which was found to correspond with 1474. This was seen upon a background of continuous spectrum in which dark lines were made

* The B line has not as yet, as far as we are aware, been seen reversed in the spectrum of the chromosphere.

out with certainty. The slit was then carried outwards, until at a distance of more than 1° from the sun's centre 1474 was lost sight of.

tangent at the sun's limb at the point of last appearance of the sun. Not caring to spend my time upon the spectrum of the prominences, I looked up at the eclipse. . . . .

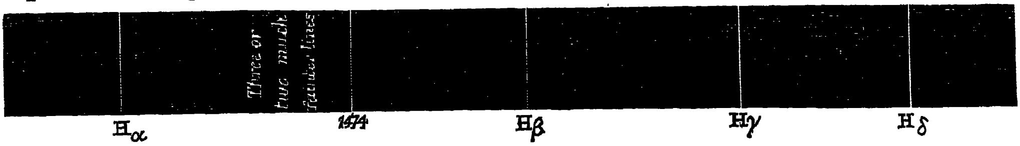


Diagram to illustrate the spectrum of the inner corona observed by Stone.

(p. 44.) The outer corona appeared to me quite sufficiently bright for the examination which I intended to make. I therefore asked my wife to sweep the telescope quite away from the inner corona, out into the middle of the branch B, and to keep it directed to that part of the corona until I gave further instructions. This was done. On sweeping across the inner corona the hydrogen lines were seen extended across the slit; a line somewhere in the green, and two or more much fainter lines of less refrangibility than the green line, were also seen. There was also a pretty bright spectrum which appeared continuous, but the spectroscope was swept rather rapidly over the inner corona, and I do not feel myself in a position to speak with any great certainty of its spectrum.

Spectrum of inner corona.

Spectrum of outer corona.

When the telescope had been fairly directed to the middle of the branch B,* the spectrum was carefully examined. I could, in the spectrum of this part of the corona, only distinguish one bright line. If there were any other bright lines present, they were so much fainter than the line

Diagram to illustrate the spectrum of the outer corona observed by Stone.†

referred to that I could not, after a careful examination, see them. But besides the one bright line there were certainly dark or absorption lines present in the spectrum, although they were seen with great difficulty. I next asked to have the telescope slowly moved towards the extreme visible limit of the branch B, and requested that this should be continued

* See the woodcut given in Vol. xliii., p. 43.

† The dark lines seen by Mr. STONE are not given in the woodcut, as their places were not determined.

until I stated that I had lost the bright-line spectrum. This was done. This line, which extended across the slit, gradually became fainter, until I lost sight of it from extreme faintness. Stone's observation.

At that time my wife states that the extreme visible limit of the branch B had been reached (judged from its position on the cross-wire of the finder), and that the moon's limb, but not all of the inner corona, was out of the field of the finder. The field of view of the finder is very nearly three diameters of the sun, and the part of the corona under examination when the line-spectrum was last seen must therefore have been more than a degree from the sun's centre.

This examination having been completed, the telescope was again directed to somewhere about the middle of the branch B. The small telescope of the spectroscope was unclamped, and the spectrum examined from end to end with the greatest care; but I could not perceive any other bright line than the one seen before. The telescope of the spectroscope was then clamped, and a careful bisection made with the micrometer wire. Dark lines seen in the spectrum of the corona.

The telescope was then left untouched; but another examination for the presence of absorption lines was made, with the same result as before. I felt convinced of their presence, but they were very faint and seen with great difficulty.

As soon as the totality was over the micrometer was read, and a bisection of the line E and the nearest of the *b* lines made, to prevent any possibility of mistake.

The bright line turned out to be line 1474 of Kirchhoff's scale. The wave-length from my observations was 5312, which appears to differ about the breadth of the D lines apart from the value determined for the line seen in the spectrum of the corona by Young. I was not certain, however, that the line measured by Young belonged to the outer corona. The inner corona extends in some directions to 10′ or 11′ from the sun's limbs. At one of the most important of the Indian stations at the eclipse of 1871, it is reported that there was no visible spectrum of the corona at 5′ from the sun's limb. The difference, however, between the wave-length of the line examined by me and that examined by Young is smaller than I could answer for with my dispersion, and I have no doubt *now* of the identity of the wave-lengths of the lines seen; but I should have been most reluctant to have assumed this without proof.

Stone's observation.

My observations refer to the outer corona; and I knew, and know, of no grounds upon which the identity of the inner and outer corona could have been assumed. I therefore regarded, and regard, the determination of the wave-length of the line seen as important.

Summary of observations.

(p. 46.) My spectroscopic examination of the corona was almost entirely confined to the outer portions. I cannot, therefore, speak with confidence of the spectrum of the inner corona. My plan was to confine my attention to the outer corona, and to this plan I adhered. I do not regret the restrictions thus imposed upon myself; and should I ever have the good fortune to see another total solar eclipse, I would restrict myself in like manner to one or two points which I deemed important, although of course not necessarily the same as those to which I confined my attention in 1874.

All I can say with respect to the spectrum of the inner corona amounts to this: that I saw the hydrogen spectrum over a considerable portion of it, with the lines the full length of the width of the slit; that I saw a bright line which I have every reason to believe to be the same as that seen in the spectrum of the outer corona, and two—I believe three—fainter lines of less refrangibility, and a spectrum which appeared to me continuous, but rich in red light. I believe that the Fraunhofer lines were not visible in the spectrum of this part of the corona; but my examination was, as I have stated, too imperfect to allow me to express any confident opinion upon the point. In the spectrum of the outer corona I feel certain that the Fraunhofer lines were present.

Spectrum rich in red light.

No attempt was made to observe the general reversion of the Fraunhofer lines at the end of the totality.

SUGGESTIONS FOR SPECTROSCOPIC OBSERVERS OF FUTURE ECLIPSES.

Suggestions prepared by Prof. Young in 1871.*

1. Observations of the instant of first and last contact by means of the occultation and reappearance of the chromosphere.

2. Careful examination of the cusps during the partial phase, to ascertain if the moon's limb appears to modify in any way the spectrum of the chromosphere.

Brushes of red light have been reported by some observers as appearing at the cusps: if so, what is their spectrum?

3. Look for a stratum close to the limb of the sun, giving a nearly continuous spectrum just before the eclipse becomes total; and at the moment of totality giving a spectrum in which the dark Fraunhofer lines are all reversed.

Pretty high dispersive power, and a very accurate adjustment of the slit in the exact focus of the collimator, are essential; also care in placing the slit exactly tangential to the solar image, and precisely in its plane.

The observation is important. Though unlikely, it is certainly not impossible that some unusual chromospheric storm, such as Mr. LOCKYER has once seen, may have produced the phenomenon observed by Mr. PYE and myself.

4. If the stratum is found, determine the precise duration of the reversal of the lines at the commencement of the totality by means of a chronograph, and repeat the observation at the reappearance of the sun, in order to ascertain the thickness of the layer.

5. During the partial phase, especially near the time of totality, examine with the highest dispersive power available the more refrangible portion of the spectrum, for new prominence lines. If an observer can be spared, this ought to be done also during the totality. This upper portion of the spectrum needs to be much more thoroughly studied than has been done.

6. With a spectroscope of high dispersive power attached to a telescope of large angular aperture, giving an image of the sun not more than 1 cm. in diameter, examine the spectrum of the corona for new lines; especially determine whether there are any between D_3 and 1474. For this purpose the slit may be slightly widened. Also note the extension, if any, of the hydrogen lines above the chromosphere and upon the moon's disc.

7. With the same instrument and widely-opened slit search for monochromatic radial beams; and if any such exist, they can be seen through the 1474 line, in the same manner as the prominences are studied through C and F.

In this way the structure of the corona will also probably come out more distinctly, being cleared of the diffuse light from other sources.

8. Place a Nicol's prism in front of the slit of the instrument, and note the effect, if any, of its rotation upon the spectrum of the corona. But, on account of the partial polarization

* Published in the "United States Coast Survey Report" for 1870, Appendix No. 16, pp. 42-3.

of the light in its refraction through the prisms, any results thus obtained must be received with reserve, and carefully checked.

9. Examine the appearance of the sun through a so-called meteor-spectroscope (having no slit or collimator). So much of the corona as gives the monochromatic light will be *distinctly* seen, while the rest will be made indistinct. The same object may be obtained by looking at the sun with the eye naked, and armed with a small telescope, through a prism; or, better, a train of five or six prisms.

10. Repeat the observations of Prof. PICKERING in 1869, and of Messrs. ABBAY and PYE in 1870, with an integrating spectroscope—*i.e.*, a simple chemical spectroscope, unattached to a telescope. There remain discrepancies which need to be cleared up. It is *exceedingly* important that, in all cases when possible, the observer of the spectroscopic phenomena of totality should have had his eyes carefully prepared by previous seclusion in darkness for some four or five minutes.

Further Suggestions.

1. As the solar crescent becomes narrow, an observer provided with an analyzing spectroscope of large dispersion should bring his slit up to the cusp, and examine the bright lines in the solar spectrum, especially those which Prof. HENRY DRAPER has identified with lines in the spectra of oxygen and nitrogen. He should notice whether any of them can be traced beyond the rest of the solar spectrum, or whether they are dimmed or are entirely absent in the part of the spectrum corresponding to the extremity of the cusp. If they are found to be absent, he should record the distance from the cusp at which they are last visible; and the manner in which they are lost sight of should be carefully observed. Thus, for example, it should be noted whether they degrade rapidly in intensity, whether they all extend to the same altitude, and whether they grow narrower before disappearing. The manner in which the dark lines of the solar spectrum are prolonged into the bright lines of the chromosphere, which may be visible at the cusps, should also be studied.

2. The spectrum obtained from the cusp when the crescent is very narrow might be photographed with an analyzing spectroscope.

3. An attempt to photograph the spectrum of the reversing layer might be made with an ordinary short-focused camera, mounted with a prism * in front of the lens on an ordinary stand without clock motion. The exposure should be made by depressing a button, or by some other simple method, by an observer with a direct-vision integrating spectroscope, at the moment when he first sees the bright-line spectrum. The camera should be focused for the violet end of the spectrum. A prism of 45°, of flint glass of very moderate density, would give a dispersion of more than two degrees between the C and the H images, and a still greater

* It is, perhaps, hardly necessary to mention that the prism ought to cover the whole aperture of the camera lens. If it does not, a stop should be made use of. The refracting edge of the prism should, of course, be turned so as to be parallel to a tangent at the centre of the disappearing crescent.

dispersion for the photographic spectrum. If, therefore, a camera of only ten inches focus were used, a spectrum of nearly half an inch in length between the C and the H images would be thrown upon the plate.

4. The disappearance of the crescent might be observed with a spectroscope of high dispersive power, without a slit, attached to a telescope. The eye should be shielded at the commencement of the observation by a wedge of dark glass, which should not be too rapidly withdrawn. The observer who makes this observation should familiarize his eye with the grouping of some of the bright lines of the spectrum, as well as with the grouping of some of the adjacent Fraunhofer lines which have been seen reversed at the base of the chromosphere, and should endeavour to determine whether any images corresponding to the bright lines are seen at the moment when the spectrum first ceases to be continuous.

5. After the commencement of totality, the relative brightness of the red and the violet end of the continuous spectrum of the corona should be compared with the relative brightness of similar parts of some standard continuous spectrum, which can afterwards be compared with the solar spectrum. In observing the continuous spectrum of the corona, the slit, which should correspond to an arc of, say, 10′, should be placed radially to the sun's limb, and it should be noted whether the red end of the spectrum is relatively brighter on the side of the field corresponding to the moon's limb than on that corresponding to the upper parts of the corona. A similar observation should be made when the slit is placed across the edge of a rift, with regard to the relative brightness of different parts of the continuous spectrum from the matter within the rift, and from the brighter part of the corona.

6. The continuous spectrum of the corona might also be observed with an analyzing spectroscope and a double-image prism,* placed so that the two oppositely polarized images of the spectrum are seen side by side just touching each other. With the slit of the spectroscope placed radially to the sun's limb, the observer should note the intensity of different parts of the spectrum in the two images. If the spectroscope is furnished with a single moderately dense flint-glass prism of 45°, the depolarization caused by the inclination of the surfaces of the prism will not be sufficient, judging from the polarimeter observations of 1870 and 1871, to counteract the radial polarization of the corona. And if an excess of red light † is emitted by incandescent particles in the lower parts of the corona, the observer may expect to find a greater difference between the brightness of the two images of the violet end of the spectrum than is observable in comparing the two images of the red end.

7. The observation of RESPIGHI should be repeated with a prism of rather larger angle ‡

* The reason for preferring a double-image prism to the Nicol's prism, recommended by Prof. YOUNG, is that much less light is lost in the passage of a ray through a double-image prism than in its passage through a Nicol, and there will also be an advantage in having the two oppositely polarized images in the field at the same time for comparison.

† See the note on pp. 353 and 354, referring to STONE's observation respecting the richness of the red end of the continuous spectrum of the corona.

‡ The prism used by RESPIGHI gave a dispersion of 12′ between the C and the F images. With a prism of 20°, of flint-glass of moderate density (such as that given as No. 23 in Fraunhofer's table of refractive indices), the distance between the C and the F images would correspond to twenty-four minutes of arc. The power used with the telescope should not be too high, but should be adapted to utilize the whole of the light derived from the object-glass.

in front of the object-glass, and a low-power eyepiece. The observer should especially notice whether any rifts or structure corresponding to the coronal structure which is seen in photographs and with the naked eye, can be recognised in the monochromatic images. The instrument might be mounted so as to describe a cone round the sun's place, with a semi-vertical angle equal to the deviation of the prism. The first observation might be made with the edge of the prism approximately parallel to the sun's axis, so that the equatorial regions of the monochromatic images would be most displaced. The telescope and prism should then be turned so as to displace the images in the direction of the sun's axis, and permit of the examination of the polar regions of the monochromatic images.

8. The D_3 line and faint lines between D_3 and 1474 should be searched for in the lower regions of the corona. For this purpose an analyzing spectroscope of low power and small dispersion should be made use of. The slit should not be too widely opened, and all extraneous light should be excluded from the field.* A diaphragm might be placed in the principal focus of the observing telescope, which would just exclude the C and 1474 lines. The region above F should also be examined.

9. The relative brightness of the 1474 line, and of the hydrogen lines in the spectrum of the corona, and of the same lines as seen in the spectrum of a prominence, should be compared. If the faint lines between 1474 and D_3 are visible, their relative brightness at various altitudes should be noted.

10. An observer using an analyzing spectroscope of one prism, with a collimator and telescope constructed to utilize the whole pencil, should endeavour to determine the distance from the sun's limb to which the 1474 line can be traced, in the neighbourhood of the sun's poles as well as in the equatorial regions.

The area of the hydrogen region and the faint line regions should also be similarly explored, and the observation of HERSCHEL with regard to the 1474 line extending into the area of the rifts should be carefully repeated.

In making these observations, the observer should assure himself that no dispersion of light is caused by cloud or particles floating in our own atmosphere which would be sufficient to vitiate his results. If the lines of the prominence spectrum cannot be detected extending upon the disc of the moon, it may probably be assumed that the fainter light of the corona is not sensibly dispersed. A. C. RANYARD, 1877.

* It seems evident from former observations that the light of the continuous spectrum of the corona is quite sufficient to permit of moderately fine cross-wires being seen. With these the position of the faint lines might be registered.

CHAPTER XLIV.

PHOTOGRAPHS AND DRAWINGS OF THE CORONA.

Drawings of the corona which have been selected for publication.

THE number of drawings of the corona which have been published is so great that it would have involved considerable expense to have attempted to reproduce them all. We have therefore restricted ourselves, in the selection which it was necessary to make, to a few of the earlier pictures of the corona, and to the unpublished drawings of later eclipses that have come into our hands which do not appear to be mere diagrams intended to illustrate the general effect observed. To make the collection more complete, a few woodcuts are added of some of the more remarkable published drawings of the corona, and plates are given at the end of the volume of the more important photographs* of the corona made previously to the eclipse of 1875.

Scale and orientation of woodcuts.

In order to facilitate the comparison of the drawings of the corona of which illustrations are given, all the woodcuts, with the exception of a few which would have been too large for the page, have, in pursuance of a suggestion of the ASTRONOMER ROYAL, been made on one scale, and the coronas have been turned round, or oriented, so as to bring the sun's axis vertical upon the page with the north pole uppermost. The data are always given from which the position of the sun's axis has been determined. It will be seen that in the case of the lithographs and steel plates at the end of the volume, the rule with regard to the uniform scale has not always been followed, as it would have been difficult to have given the details visible on some of the photographs on as small a scale as that adopted for the woodcuts—

* These do not include Lord LINDSAY's photograph of the corona of 1870, which was so fogged as to be useless, nor photographs of prominences taken during solar eclipses—such as those of Mr. DE LA RUE, taken during the eclipse of 1860, those of Colonel TENNANT, taken during the eclipse of 1868, or those of Professor HIMES, taken at Ottumwa during the eclipse of 1869; though some of these, especially the Ottumwa photographs, show some of the brighter structure of the lower parts of the corona.

viz., 1·25 inches for the moon's diameter. The lithographic plates from the photographs of the eclipses of 1851, 1860, and 1869, and the plate from the Jerez photograph of 1870, as well as the steel plates from Lord LINDSAY's and Colonel TENNANT's photographs of the eclipse of 1871, have consequently been made on double the scale of the woodcuts, or 2·5 inches for the moon's diameter. The large plates, showing the structure visible on the 1871 photographs, are on eight times the scale of the woodcuts, or 10 inches for the moon's diameter.

Data from which the position of the sun's axis has been determined.

In determining the orientation of drawings upon which the position of the north point or other orienting lines have not been marked, it has been assumed that the highest part of the drawing upon the page corresponded to the highest part of the corona above the horizon, unless there appeared to be sufficient evidence that the drawing corresponded to the inverted image, or had been oriented by the draughtsman in some other manner—for example, with the north or south point uppermost. My thanks are due to Mr. CHRISTIE and Mr. MARTH for having checked most of the calculations necessary for this purpose.

Difficulty of drawing the corona.

In casting the eye over the pictures of the corona which have been brought together in the present volume, the reader may possibly in the first instance be more struck by the dissimilarity of the drawings than by their likeness. But when we remember the short time during which totality lasts, the various matters to which the attention of the observer may be directed, the different methods which he may select for representing what he sees,* and the difficulties which even a skilled

* Many observers give an outline intended to indicate the extreme limits of the area within which they have been able to detect the light of the corona—an area which, it should be remembered, depends upon the clearness and illumination of the surrounding sky, as well as upon the condition of the observer's eye. Within this area they have added shading which, it may no doubt always be assumed, has been added after totality, and corresponds with the observer's memory of the relative brightness of the different parts of the corona. A few observers give contour lines indicating areas of greater brightness. Others attempt to give outlines of such of the brighter structures within the field of the corona as caught their attention during totality. Others, again, make drawings in which the appearance presented by the corona is combined with rays indicating the dazzling appearance of the prominences and chromosphere in the lower parts of the corona. Confusion also arises from the very different methods which different draughtsmen employ for representing bright areas and various intensities of shade or brightness.

artist encounters in attempting to represent an object like the corona,* it is perhaps remarkable that there should be as much similarity between the various drawings and descriptions of the corona as will on a careful comparison be found to exist.

The discrepancies between the drawings of the corona which were examined without having been first oriented and reduced to a common scale appeared so great, that up to a recent period many astronomical writers doubted the existence of the corona as a solar appendage, and believed that it was principally due to atmospheric causes. An examination of the drawings made during the eclipse of 1860 would, however, have been enough to convince an impartial critic that certain curved and crossing rays were seen at similar parts of the corona by observers at different stations; and an examination of the drawings and photographs made during later eclipses still more clearly shows that similar rays and curved structures are visible in the corona from stations several hundred miles apart. The corroborative evidence with regard to the details of the corona which have been observed during different eclipses will be discussed in the sections of the present chapter devoted to the separate eclipses. **Corona formerly thought to be an atmospheric phenomenon.**

It will probably facilitate the comparison of the drawings and photographs of the corona referred to in the present chapter, if attention is in the first place directed to the laws which appear to hold with regard to the arrangement of the structure of the corona which was visible during the eclipse of 1871. It is evident that the corona changes greatly from eclipse to eclipse; but owing to the excellence of the photographs taken during the eclipse of the 12th December, 1871, we are probably better acquainted with the corona of that date than with any other.

The Corona observed during the Eclipse of 1871.

If the reader will turn to the steel plates from the photographs of the 1871 eclipse, he will observe two marked rifts—one to the **Symmetry of the corona of 1871.**

* These difficulties will more readily be appreciated when we remember the discrepancies which exist between the drawings of a well-known telescopic object like the nebula in Orion—an object which may be observed for many hours at a time, and with which the draughtsman can, if he wishes it, repeatedly compare his drawing.

north and the other to the south. The line joining the base of these rifts divides the corona into two halves, which are roughly symmetrical. It will be noticed that the line about which the corona appears to be symmetrical does not coincide with the sun's axis.

Synclinal groups and synclinal zones.

On each side of the great northern and southern rifts are groups of incurving structure, which occupy an arc of some 40° on the moon's circumference. The curved rays on either side of these groups all bend inwards, and the straighter rays appear to be inclined from the radial direction towards parallelism with the axes of the groups. It will be convenient to speak of these groups of incurving structure as synclinal groups, and of the zones of which they form a part as the northern and southern synclinal zones. We shall speak of the region between the two zones as the equatorial region, and of the regions surrounded by each of the zones as the northern and southern polar regions.

Structure within the polar rifts.

Continuing our examination of the plates from the 1871 photographs, it will be seen that in the polar regions there are several narrow straight or but slightly curving rays, none of which are quite radial to the sun's limb; there is nothing definitely to guide the judgment in determining whether these rays spring from the area immediately about the sun's poles, or whether they belong to the zones of synclinal structure, and are only seen in the polar regions by projection. On the one hand, it will be noticed that these rays do not exhibit a branching structure or double curvature, such as is observable in some of the rays at the edges of the groups of synclinal structure; but on the other it will be borne in mind that rays curving from or towards the observer would be projected into apparently straight rays, and possibly some of the structures which have the appearance of branching rays in the synclinal groups may be due to rays of different curvature seen projected one upon another. Rays similar to those at the edges of the synclinal groups upon the limb would, if springing from the nearer or further parts of the synclinal zones, be seen projected in the polar regions to a considerable altitude above the sun's limb—probably quite as high as the rays visible in the photographs.

Rays inclined to the radial.

On the supposition that these rays belong to the synclinal zone, their inclination to the radial would indicate that they are not only inclined

away from the sun's axis, but that they are also inclined to the east or west. It is worthy of remark that inclination to the radial cannot be a mere effect of perspective. For a line passing through the sun's centre could not be projected so as not to be radial to the sun's limb. We have, therefore, evidence that many of the rays, especially those seen towards the edges of the synclinal groups, are inclined at considerable angles to the normal to the surface of the photosphere. It is difficult to conceive how explosions within a gaseous body like the sun can give rise to oblique rays, but the evidence for the existence of such rays in many coronas, besides that visible during the eclipse of 1871, is overpowering. Some of these oblique rays are straight, or nearly straight, while others show considerable curvature, and others bend over in one direction in their lower parts, and are again carried slightly in a contrary direction above. This double curvature or contrary flexure is also evident in some of the tree forms, which on a gigantic scale remind the observer of a common type of prominence to be seen in the chromosphere.

Inclination to the radial not an effect of perspective.

Curved rays.

The existence of these curving forms and rays showing contrary flexure is a matter of considerable importance, as they appear to indicate the existence of an atmosphere with currents carrying the matter of which the structures are composed with different velocities at different altitudes. The tree-like structures also seem to indicate the spreading out within a resisting atmosphere of matter rising from below. It will also be remembered that the observations of some spectroscopic observers * point to the existence of a gaseous envelope extending to a height of at least 8′ or 10′ above the sun's limb, and giving lines which are equally bright within the area of the rifts and upon the brighter structure of the corona.

Evidence with respect to the existence of an atmosphere in the region of the lower corona.

On turning to the groups of coronal structure given in Plates X. to XVII., it will be noticed that none of the tree-like expansions are to be found in the upper half of the corona, though there are several forked and curving rays whose form it seems difficult to account for by the action of explosive forces and gravity alone: take for example the

Tree-like structures found only in lower part of corona.

* See *ante*, pp. 365-67. The observations of Prof. EASTMAN made during the eclipses of 1878 also point to the same conclusion.

forked summit of η in the F group, and the curved and branching structure γ in the H group. It will, however, be seen that there were more straight rays, and fewer contorted structures (indicating the existence of a resisting atmosphere), in the upper part of the corona of 1871 than in the lower part.

No evidence of the action of a repulsive force in the corona driving matter away from the sun.

The forms of the structures do not seem to afford evidence of a repulsive force similar to that which drives the matter of a comet's tail away from the sun. On the contrary, forms like A θ seem to indicate that the bright coronal matter occasionally falls again towards the sun in a stream or mass, after having been driven upward into the higher parts of the corona in an oblique direction. In most instances, however, the rays which extend into the outer parts of the corona grow gradually fainter in their upper parts without exhibiting any change of direction. Many of these rays grow somewhat broader, and a few appear to have spurs or branches, or are forked near their summits. See for example C α, D β, F η, G α, and G σ.

In passing from the lower to the higher parts of the corona, it will be noticed that there is no abrupt change in the brightness of the corona, such as might be expected to correspond to a region of dissociation, or to any other abrupt change in the physical state of the coronal matter.

General Symmetry of the Corona with respect to the Sun's Axis.

A casual observer examining the woodcuts made from the oriented drawings of the corona must be struck with the symmetry with regard to the sun's axis, or with regard to a line not very far removed from the sun's axis, which most of the pictures of the coronas which have been observed during the various eclipses exhibit. This symmetry is strikingly seen in the photographs taken during the eclipses of 1851, 1860, 1869, and 1871, but is not so evident in Mr. BROTHERS' photograph of the eclipse of 1870. It is, however, very traceable in the denser photograph of Mr. WILLARD, taken at Jerez during the same eclipse, and also in many of the 1870 drawings. It will be noticed that in most instances there is a difference of some 5° or 10° between the position of the axis of symmetry and the sun's axis. In order to deter-

Axis of symmetry appears not to coincide with sun's axis.

mine the position of the projection of the sun's axis upon the photographic plates, it was necessary in the first instance to find the position of the north point, or of a line corresponding to the direction of the sun's diurnal motion, upon the plate. The method by which these orienting lines have been laid down will be explained in detail in describing the different photographs. It is only necessary here to draw attention to the fact that, in the case of the 1869 and 1871 photographs, the error in the position of the north point probably does not amount to as much as 5°. The position of the sun's axis with regard to the north point has been calculated by making use of CARRINGTON's elements of the position of the solar equator.

Two classes of coronal drawings.

1. Drawings of structures in corona.

2. Outlines of areas of equal brightness.

It will be seen that the drawings of the corona, which are not mere diagrams intended to illustrate the general effect observed, may be divided into two classes: 1. Drawings in which the observer has attempted to represent the structures within the field of the corona which caught his eye during totality; and, 2. Drawings in which the observer has attempted to indicate the limits of the area within which he could detect the light of the corona, or in which he has given contour lines, or shading, corresponding to areas of equal brightness.

A connection can usually be traced between the two classes of drawings, for the groups of coronal structure are found to correspond to the brightest* parts of the corona; and the contour lines marking out the limits of the coronal area, or of the areas of greater brightness within the corona, usually rise to the greatest height above the moon's limb at places corresponding to the principal groups of coronal structure. Thus where the corona is given with a quadrilateral outline in drawings of the one class, rays or groups of structure are shown in drawings of the other class in positions corresponding to the diagonals of the quadrilateral.

It will be found that as a general rule the outline or contour drawings of the corona are rather more symmetrical with respect to the sun's axis than drawings in which the observer has attempted to

* This is shown to be the case by the photographs in which the coronal structures are to be traced by means of the denser photographic action to which they have given rise. See also the observation of Wilson with a dark wedge during the eclipse of 1860.

Outline drawings of corona most symmetrical.

depict the rays and brighter structures within the corona; and a little consideration will show that, however symmetrical may be the arrangement of the rays and structures with respect to the sun's axis, the appearance of symmetry must be greatly interfered with as they are seen in projection by an observer on the earth. Rays inclined to or from the observer would have their apparent inclination with respect to the sun's axis materially altered, and long rays in the nearer and further parts of the corona would frequently appear to spring from a part of the sun's limb corresponding to a different zone of heliographic latitude. In examining the drawings showing coronal rays, and the photographs in which coronal structure can be made out, these considerations must continually be kept in mind.

Symmetry of the drawings and photographs of the Corona made during various eclipses.

1715·3.—It does not seem probable that there can be any serious error in the orientation which has been adopted for the drawings of COTES and WALKER, as it makes "the longer and brighter branch of the cross lay very nearly along the ecliptic," as mentioned in the text. The drawings thus represent a roughly symmetrical corona, with rays that extended to a great distance from the sun's limb in the equatorial regions, and rays in the polar regions which also attracted the attention of the observers. COTES mentions that the shorter branch of the cross which corresponded with the polar rays "was so weak" that he did not constantly see it. The crossing lines were probably intended to limit the length of this branch, and not to represent coronal structure.

1766·2.—In the one drawing which we have of this eclipse, the symmetry of the corona with regard to a line inclined some 20° to the sun's axis is moderately evident. The position of the sun's axis must, however, be considered as only very approximately determined.

1842·5.—The drawings of the corona which were made during this eclipse appear to be mostly mere diagrams illustrating the general effect observed. The drawing by BIELA, however, of which a plate is given in the *Annalen der Viener Sternwarte*, vol. xxii., shows a great arm of light extending from the moon's western limb to a distance of more

than a solar diameter. BIELA mentions that other observers saw a similar excrescence from the other side of the corona. He was using a telescope with a small field, and only observed the western section of the corona.

Symmetry of the coronas of various eclipses.

1851·6.—The symmetry of this corona with regard to a line not very far removed from the sun's axis is well shown in the daguerreotype taken at Konigsberg (see Plate 2). The position of the sun's axis must, however, be considered as only very approximately determined. The drawings made during this eclipse appear to be mere diagrams illustrating the general effect observed.

1858·7.—A certain amount of symmetry with respect to the sun's axis is to be traced in the only drawing we have of this corona. The coronal rays extend to the greatest distance from the sun's limb in the equatorial regions, and the four great groups of incurving rays are, roughly speaking, symmetrically arranged with respect to the sun's axis.

1860·5.—The symmetry of the corona visible during this eclipse with regard to a line not very far removed from the sun's axis is evident from the photographs taken at Desierto de las Palmas (see Plate 3). The two narrow rifts, or gaps, a little above the centre of the east and west limbs are due to a wire which was stretched across the field just in front of the photographic plate. Assuming that the wire was correctly placed in an east and west position, it does not seem probable that the orientation which has been adopted can be in error as much as 10°. The axis of symmetry does not appear to coincide accurately with the sun's axis, but the angle between the axis of symmetry and the sun's axis is probably not as great as the probable error of the orientation. The symmetry of the corona is also well shown in the drawing made by TEMPEL.

1867·7.—In the one drawing we have of this eclipse, the symmetry of the corona with respect to the sun's axis is clearly marked both as regards the great rays in the equatorial regions, and the curving rays at the poles.

1868·6.—The curving rays in the drawing by POPE HENNESSY seem to indicate a symmetry of this corona with regard to a line not very

Symmetry of the corona of 1868·6.

far removed from the sun's axis. POPE HENNESSY's drawing has been oriented by means of the prominences, which are not very accurately given; and the position of the sun's axis as laid down in the woodcut must therefore be considered as somewhat doubtful. The drawings by BULLOCK and SUTTON, though very different from that by POPE HENNESSY, show a decided symmetry with respect to the sun's axis. The drawings by POGSON, WALKER, and WINTER, given in POGSON's eclipse report, are of the quadrilateral type, and are roughly symmetrical with respect to the sun's axis. The orientation of all these drawings may be easily recognized from the position of the great prominence, which was situated at about 60° from the north point of the sun's axis towards the east. The five drawings of the corona given in STEPHAN's report also appear to be roughly symmetrical with respect to the sun's axis.

1869·6.—The symmetry of the corona visible during this eclipse with regard to a line not very far removed from the sun's axis, is evident from the photograph taken at Shelbyville (see Plate 4). According to the orientation which has been adopted, there seems to be an angle of some 10° between the axis of symmetry and the projection of the sun's axis. The orientation adopted in Plate 4 was obtained by means of the prominences, which were identified with prominences shown upon the Ottumwa photographs. The position of the prominences in the Ottumwa photographs was obtained from cross wires in the field of view; and unless the wires were very carelessly placed in position, it seems improbable that the error in the orientation of Plate 4 can amount to as much as 5°. SCHOTT's drawing corresponds with the photograph as to the position of the chief groups of coronal structure; and though there is a ray or group of structure in the eastern equatorial region to which there is no corresponding ray in the western equatorial region, the drawing on the whole represents the corona as symmetrical with respect to the sun's axis. The drawings by CUTTS, MEEK, and M'LEOD, of which lithographic copies are given in Figures 5, 9, and 12 of Plate 25 of the United States Coast Survey Report for 1869, fairly correspond with the drawing by SCHOTT: all of them show the four great rays or groups of structure in the N.W.,

N.E., S.E., and S.W. sections of the corona. BLAKE's outline drawing, given on p. 30 of the United States Coast Survey Report, shows the corona as roughly quadrilateral, the angles of the quadrilateral corresponding with the four above-mentioned groups of structure. EASTMAN's drawing, given on p. 105* of Appendix II. of the Washington Observations for 1869, shows four marked groups of incurving coronal rays; but though these are arranged nearly symmetrically about the sun, they are not symmetrically arranged with respect to the sun's axis, and do not correspond in position with the chief rays or groups of structure shown in the other drawings. GILMAN's coloured drawing, given as Plate xii. of the Washington Observations, would seem to represent the appearance of the corona as seen by an observer whose eyes were dazzled.† It will be noticed that the prominences do not correspond (or only correspond very badly) with the prominences in the photographs; and probably much reliance cannot be placed upon the outline of the corona, but it is worthy of remark that the area of greatest brightness has a quadrilateral form, which, when properly oriented, is seen to be roughly symmetrical with respect to the sun's axis.

Symmetry of the corona of 1869·6.

1870·9.—The symmetry of the corona visible during this eclipse is not very evident from the photograph of Mr. BROTHERS (see Plate 6), which was taken at Syracuse, through a gap in passing clouds towards the end of totality; but in the Jerez photograph (see Plate 5), in which the photographic action has evidently been more intense than in the Syracuse photograph, the superior brightness of the corona in the equatorial regions is at once evident; and if contour lines are traced corresponding to areas of equal intensity of the photographic action, a certain degree of symmetry with respect to a line not very far removed from the sun's axis is easily recognizable. It should, how-

* See also Plate ix. at the end of the same volume. It is possible there may be some error in the orientation of these drawings as far as regards the corona, but the prominences appear to be rightly placed with regard to the orienting lines which are given; most of the prominences, though roughly drawn, can be recognized, and appear to be in their right position with respect to the vertex as seen from Des Moines in an inverting telescope.

† Other observers have described a similar appearance. See the observations of O. Struve, given at p. 248; see also p. 253 *ante*.

Symmetry of the corona of 1870·9.

ever, be borne in mind that the outer part of the corona was cut off by a diaphragm in the Cadiz photograph. The orientation which has been adopted was obtained from the partial phase photographs taken at Syracuse, and the position of the projection of the sun's axis as given in Plates 5 and 6, probably cannot be in error as much as 15°. It is difficult to speak with any accuracy as to the position of the axis of symmetry, but according to a rough estimate there appears to be an angle of some 10° between the axis of symmetry of the Cadiz photograph and the projection of the sun's axis. The drawings made during this eclipse by MOULTON, F. H. BROWNE, HUDSON, GILLMAN, and WARRINGTON SMYTH, all represent the corona as quadrilateral, and roughly symmetrical with respect to the sun's axis. The two Spanish drawings which are given in the *Anales* of the observatory of San Fernando, show four groups of rays symmetrically situated with regard to the sun's axis, and corresponding to the diagonals of the quadrilateral outline given by the other observers. The drawing made at Cadiz shows rays which indicate a certain degree of symmetry with respect to the sun's axis.

1871·9.—The photographs taken during this eclipse at Baikul (see Plate 7), at Dodabetta (see Plate 8), and in the island of Java, agree in showing the corona as remarkably symmetrical with respect to a line not very far removed from the sun's axis. The orientation which has been adopted for these photographs was derived from a plate taken at Baikul shortly after totality, on which the sun was caused to trace a line parallel to the equator of the heavens. On the assumption that the plates exposed during totality on which the photographs of the corona were taken were in the same position with respect to the camera as the orientation plate exposed a few minutes after totality, the position of the sun's axis as given on Plates 7 and 8 at the end of the volume may probably be relied upon as being less than 2° in error. It will be seen that according to this orientation there is an angle of some 8° or 10° between the axis of symmetry and the projection of the sun's axis. TUPMAN's drawing, which was made in Ceylon before he saw the photographs, is remarkably symmetrical with respect to a line which makes an angle of about 10° with the

projection of the sun's axis in the same direction as the axis of symmetry of the photographs; but the orientation of the drawing cannot be relied upon for accuracy, as it is only derived from the vertex. JANSSEN'S, HOLIDAY'S, and FOENANDA'S drawings, though they do not correspond very accurately with the photographs, show a certain degree of symmetry with respect to the sun's axis. DAWSON, who was requested to make several drawings during totality, gives the outline of the corona as quadrilateral and roughly symmetrical with respect to the sun's axis.

Symmetry of the corona of 1871·9.

1874·3.—The drawings made during this eclipse all show a decided symmetry with respect to a line not very far removed from the sun's axis; but the orientation which has been adopted must not be relied upon for accuracy, as the position of the sun's axis has only been determined on the assumption that the highest part of the drawing corresponded to the highest part of the corona above the horizon. HALL'S, BRIGHT'S and DEGERMAN'S drawings are of the quadrilateral type, and may be described as symmetrical with respect to a line inclined some 10° or 15° to the sun's axis. In HALL'S and DEGERMAN'S drawings the axis of symmetry is inclined to the west, and in BRIGHT'S drawing to the east of the sun's axis. Miss A. HALL'S drawing is fairly symmetrical with respect to the sun's axis; and the great rays in WRIGHT'S drawing, a lithographic plate from which is given at p. 52 of Vol. XLII., also indicate a decided symmetry with respect to the sun's axis.

1875·3.—The copies of photographs given on Plate 10 of the "Phil. Trans." for 1878 show that the corona visible during this eclipse was fairly symmetrical with respect to a line which is marked upon a diagram on Plate 9 as the position of the sun's axis. The method by which the position of the sun's axis was determined is not described, but the authors of the report state that, owing to the small size of the photographs, which were taken with an ordinary photographic camera of about thirteen inches focus, they have been unable "to fix the position of the axis within one or two degrees." The drawings given on Plates 12, 13 and 14 of the same volume show very decided symmetry with respect to a line the position of which with reference to the sun's

Symmetry of the corona of 1875·3.

axis can only be inferred from the diagram on Plate 9, on which the sun's axis is marked. The drawings do not correspond in position with the photographs, and the highest parts of the drawings upon the page evidently do not correspond with the highest part of the corona above the horizon. Judging from the photographs, the drawings appear to have been turned through different angles by the copyists.

1878·6.—The photographs taken during this eclipse show the corona as decidedly symmetrical with respect to a line the position of which with reference to the sun's axis has not yet been properly determined. But from a preliminary comparison of the photographs with one of the orientation plates taken at Cherry Creek, it appears that the angle between the axis of symmetry and the projection of the sun's axis cannot amount to as much as 10°.

Groups of Synclinal Structure.

Existence of synclinal zones.

It will be seen that there is evidence tending to show that in many of the coronas which have been observed there have been four great groups of synclinal structure situated more or less symmetrically with respect to the sun's axis—indicating that within two broad zones of heliographic latitude the coronal structures incline together. It will also be noticed that the heliographic latitude and the breadth of the synclinal zones has differed considerably on the different occasions when evidence of their existence has been obtained.

We will now proceed to inquire whether the zones of synclinal structure are always present, and whether the evidence at our disposal renders it probable that there is a connection between the sun-spot period and the heliographic latitude of the synclinal zones.

The epochs of maximum and minimum sun-spot development made use of are those given by Dr. R. Wolf in Vol. XLIII. of the *Memoirs*. It will be convenient to speak of the lines drawn from the sun's centre so as to divide the synclinal groups symmetrically as the axes of the synclinal groups.

No evidence of synclinal groups.

1715·3 (3·3 years after a sun-spot minimum, 2·9 years before a sun-spot maximum).—The two drawings of this eclipse afford no evidence with respect to the existence of synclinal structure. If the suggestion thrown

out on p. 490 is correct, the synclinal zones must have been so depressed toward the equatorial regions that the northern and southern groups of synclinal structure appeared merged together,* and the corona must be taken to have been of a type similar to the corona observed by GROSCH in 1867·7, or to the corona of 1878·6.

1766·1 (4·6 years after a sun-spot maximum, 0·4 year before a sun-spot minimum).—It is possible that the four "cônes ou pyramides de lumière" observed by the officers on board the *Comte d'Artois* may have corresponded to four unequal groups of synclinal structure, but it seems more probable that the corona was similar in type to the corona observed during the sun-spot minimum of 1878. **Probably no evidence of synclinal groups.**

1842·5 (5·3 years after a sun-spot maximum, one year before a sun-spot minimum).—The drawings made during this eclipse which have been published show no coronal structure, and consequently do not afford any evidence with regard to synclinal groups; according to the drawing of BIELA the synclinal groups, if they existed, must have been depressed toward the equatorial regions, and the corona must have been of a type similar to the coronas observed near to the sun-spot minima of 1867 and 1878. **Synclinal groups probably depressed.**

1851·0 (3·5 years after a sun-spot maximum, 4·4 years before a sun-spot minimum).—The Konigsberg daguerreotype shows the bases of groups of synclinal structure to the south-east and south-west; and there are also traces of similar groups to the north-east and north-west. The axes of these groups make angles of about 45° with the sun's axis. It seems probable that the "conoidal form, with its base towards the sun and the curvature of its sides somewhat concave outwards," described by SWAN, corresponded to one of these synclinal groups. **Axes of synclinal groups inclined at about 45° to sun's axis.**

1858·7 (2·7 years after a sun-spot minimum, 1·4 year before a sun-spot maximum).—The four great conical groups of rays described by the observers at Paramagua and Pinheiros, as shown in the drawing given in LIAIS' report, indicate that the southern synclinal zone had a greater heliographic latitude than the northern synclinal zone. The axes of the **Axes of synclinal groups inclined at about 45° to sun's axis.**

* It will be noticed that in the corona of 1871·3 the structures are less curved on the equatorial sides of the synclinal groups than on the sides towards the polar rifts. Such groups, if depressed towards the equatorial regions, would not appear separated by very striking rifts.

northern synclinal groups made an angle of about 45° with the sun's axis, while the axes of the southern synclinal groups made an angle of less than 45° with the sun's axis.

Axes of synclinal groups probably inclined at about 45° to sun's axis.

1860·5 (0·4 year after a sun-spot maximum, 6·7 years before a sun-spot minimum).—The Desierto de las Palmas photographs show traces of four groups of synclinal structure; the northern edges of the north-eastern and north-western groups are easily seen; the southern edge of the south-eastern group is well marked, and both edges of the south-western group are to be seen. In TEMPEL's drawing the north-eastern, north-western and south-western groups are easily recognised, and the southern edge of the south-eastern group is also well marked. The curving rays forming the south-western synclinal group were noticed by most of the observers. WILSON, in his drawing, gives the south-western and south-eastern groups, and possibly also the north-eastern group. It appears that the axes of the synclinal groups made an angle of about 45° with the sun's axis.

Synclinal groups if they existed must have been depressed.

1867·7 (0·5 year after a sun-spot minimum, 2·9 years before a sun-spot maximum).—The drawing of GROSCH does not afford any evidence with regard to groups of synclinal structure, but it is evident that if such groups existed they must have been depressed towards the equatorial regions. If the curving structure at the poles was due to rays belonging to the synclinal zones seen in perspective, the breadth of the great groups of rays in the equatorial regions must evidently have been somewhat greater than as shown in the drawing.

Axes of synclinal groups appear to have made angles of rather more than 45° with the sun's axis.

1868·6 (1·4 year after a sun-spot minimum, 1·5 year before a sun-spot maximum).—According to the drawings of BULLOCK and SUTTON, it would appear that the axes of the synclinal groups made angles which were considerably greater than 45° with the sun's axis; but it seems that the synclinal zones were not as depressed as in the coronas of 1867·7 and 1878·6. Judging from the quadrilateral drawings of POGSON, WALKER and WINTER, and the drawings given in STEPHAN's report, the axes of the synclinal groups seem to have made angles only a little greater than 45° with the sun's axis.* Curving structures which seem to

* A similar discrepancy as to the inclination of the axes of the synclinal groups is to be noticed in the drawings of the 1874·3 corona. In WRIGHT's drawing, in which the rays extend to a great distance from the sun's limb, the synclinal groups appear more depressed than in the quadrilateral drawings of the other observers.

correspond to two synclinal groups are recognizable in POPE HENNESSY'S drawing.

1869·6 (2·4 years after a sun-spot minimum, 1·0 year before a sun-spot maximum).—The Shelbyville* photograph shows the lower parts of synclinal groups in the north western and south-western sections of the corona, and also the sides towards the polar rifts of similar groups in the north-eastern and south-eastern sections of the corona. SCHOTT'S drawing shows these groups † extending to a distance of a solar radius from the limb; and the drawings of CUTTS, MEEK and MCLEOD fairly correspond with the drawing of SCHOTT. According to the photograph and the evidence derived from these drawings, the axes of the synclinal groups appear to have made an angle of about 45°, or a little more, with the sun's axis. EASTMAN'S drawing, given in Appendix II. of the *Washington Observations* for 1869, shows four groups of incurving structure, but (possibly owing to an error in orientation) these groups do not correspond in position with the groups shown in the photograph and in the other drawings. They, however, afford evidence of the synclinal nature of the groups of rays observed in this corona, as also do the descriptions of coronal structure given by HOUGH, HILL and MURRAY, in which they compare groups of structure to "petals" and "sheaths."

Axes of synclinal groups inclined about 45° or a little more to the sun's axis.

1870·3 (0·5 year after a sun-spot maximum, about 7 years before a sun-spot minimum).—The Syracuse photograph shows a group of somewhat ill-defined but evidently synclinal structure, in the north-western section of the corona. This is the only structure visible on either of the photographs. But in the north-eastern section of the corona there is a broad-based mass, rather brighter than the rest of the corona (see plates 5 and 6), which may have corresponded to a synclinal group of structure. In the south-eastern section there is a broad ray, with slightly convex edges, which may also have corresponded to a synclinal group; but the existence of a similar group in the south-western section of the corona seems to be negatived by the presence of a rift, which is traceable in both the photographs. The drawings, however, of

Synclinal groups not well marked: query inclined at about 45° to the sun's axis.

* The steel engraving given as Plate 12 of the Annals of the Observatory of Harvard College, Vol. VIII., was made from the original negative, and shows the synclinal groups much better than Plate 4, which was made from paper copies from the negative.

† As well as another group in the eastern equatorial section of the corona.

the observers at San Lucar and San Fernando show four groups of structure, with axes inclined at about 45° to the sun's axis; and the quadrilateral drawings by MOULTON, F. H. BROWNE, HUDSON, GILLMAN, and WARRINGTON SMYTH indicate that there were four areas of greater brightness in positions corresponding to the diagonals of the quadrilateral. It is worthy of remark that in the San Lucar drawing the outer rays of the groups are convex; and the curved rays in the south-western section of CORALLO's drawing should also be noticed.

Axes of synclinal groups make angles of from 30° to 40° with the sun's axis.

1871·9 (1·3 year after a sun-spot maximum, about 6 years before a sun-spot minimum).—The axes of the four synclinal groups make angles of from 30° to 40° with the sun's axis. But it will be noticed that the diagonals of the quadrilateral drawing of the corona, hurriedly made by DAWSON, make angles considerably greater than 45° with the sun's axis. In this corona, and in the corona of 1870·9, as well as in that of 1860·5—all near to periods of sun-spot maxima—it seems that there was no very marked difference between the extent of the corona in the polar and equatorial regions.

Axes of synclinal groups make angles greater than 45° with sun's axis.

1874·3 (3·7 years after a sun-spot maximum, about 3½ years before a sun-spot minimum).—According to the drawings of WRIGHT, HALL, Miss ALICE HALL, BRIGHT and DAGERMAN, it would seem that the axes of the synclinal groups made angles considerably greater than 45° with the sun's axis. WRIGHT's drawing is of the same type as BULLOCK's drawing of the corona of 1868·6; both epochs are about half-way between periods of sun-spot maxima and sun-spot minima.

Axes of synclinal groups make angles of about 45° with the sun's axis.

1875·3 (4·7 years after a sun-spot maximum, about 2½ years before a sun-spot minimum).—The copies of photographs given on Plate 10 of the "Phil. Trans." for 1878, show clear evidence of four groups of synclinal structure, situated nearly symmetrically with respect to the line which is given as corresponding to the position of the sun's axis. The axes of the synclinal groups make angles of about 45° with the sun's axis. SHORE's drawing of the corona (Plate 12) also affords evidence of four groups of synclinal structure, corresponding with the groups in the photographs.

Eclipse of 1715, May 2nd.

The two drawings, though described as the most remote from one another in appearance that could be chosen, agree within a few degrees as to the position of the principal rays or groups of structure. If the "longer and brighter branch of the cross" was intended to represent rays extending to a great distance from the sun's limb in the equatorial regions, the shorter branch, which is described as "so weak" that COTES could "not constantly see it," would correspond to rays from the polar regions.* A similar drawing,† with long rays from the polar and equatorial regions, forming a rectangular cross, was made by Professor ABBE during the eclipse of 1878·6, when, from the evidence of the photographs and the drawings made by most other observers, it appears that though the corona extended to a great distance from the sun's limb in the equatorial regions, there were only a few comparatively faint and slender rays to be seen in the polar regions. These, however, probably by reason of their isolation from other rays, caught the eye of most of the observers, and were represented by Professor ABBE, as well as another observer near Denver, as long rays of nearly equal brightness with those in the equatorial regions. The original drawings from which the woodcuts in EDLESTON'S "Correspondence of Newton and Cotes" were made, have been inquired for at the library of Trinity College, but they have not at present been found.

Prof. Cotes, CAMBRIDGE,
Mr. Walker. 2nd May, 1715.

"Correspondence of Newton and Cotes," edited by Edleston, p. 181.

(*Letter from Cotes to Newton.*)

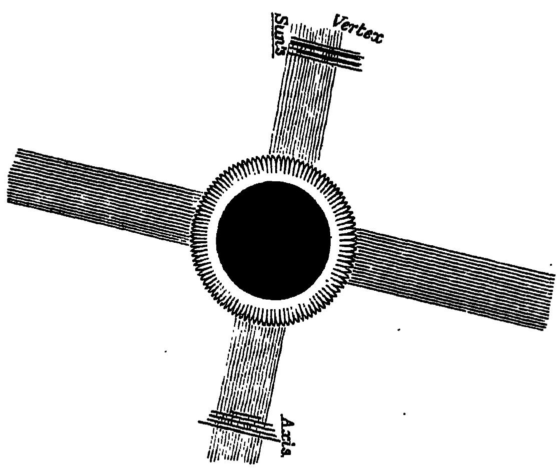
"I take this opportunity of giving you an account of what was observed by us during the time of the sun's total obscuration in the late eclipse, as far as I judge it to be of any moment. The sky was

* See the note on p. 503.

† A woodcut from this drawing was published in the *Daily Gazette*, Colorado Springs, 7th August, 1878.

Observation of Cotes, Eclipse of 1715.

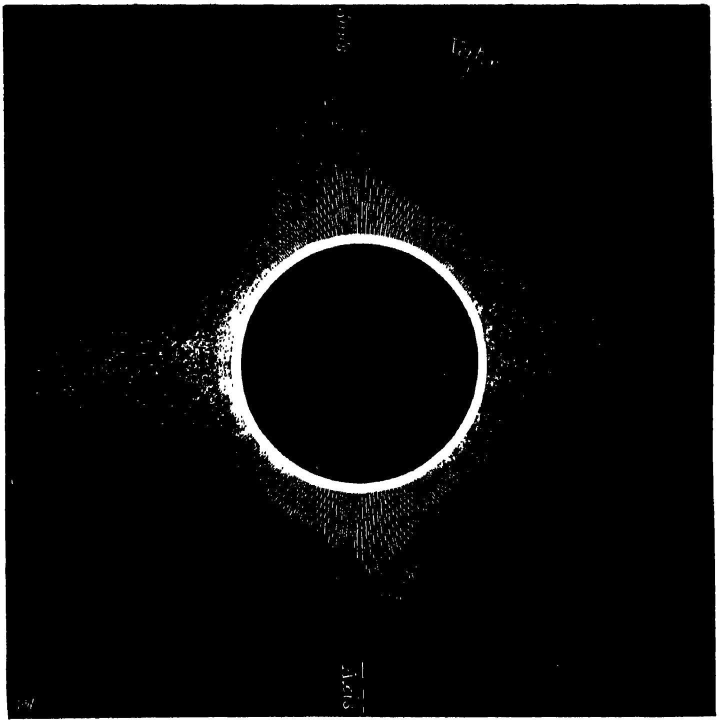
perfectly clear all the morning till about two or three minutes after the recovery of the sun's light. It surprized us to find so great a quantity of light remaining in the middle of the eclipse: I think it did very much exceed the brightness of the clearest moonlight nights. A friend assur'd me he could very easily and distinctly read the smallest letters engraved about Mr. Whiston's 'Scheme of the Heavens,' which he had in his hand at the time. We saw the planets Mercury and Venus, with some fixed stars; but they appeared with far less splendour and fewer in number than we expected, or than they might have done by moonlight. I took the greatest part of this remaining light to proceed from the ring which encompassed the moon at that time. As nearly as I could guess, the breadth of this ring was about an eighth, or rather a sixth part of the moon's diameter; the light of it was very dense where it was contiguous to the moon, but grew rarer continually as it was further distant, till it became insensible; its colour was a bright clear white. I saw this ring begin to appear about five seconds before the total immersion of the sun's body, and it remained visible to me as long after his emersion. I did not apply myself to observe whether it was of the same breadth in all its parts during the total obscuration. Mr. Walker, a Fellow of our College, whom I can very well depend upon, assur'd me he was very certain it was not. He says he took notice with a great deal of attention that at first



Cotes' drawing of the Corona of 1715. May 2nd.*

* The above woodcut and that on the opposite page have been oriented on the assumption that the highest part of the woodcuts in Edleston's "Correspondence of Newton and Cotes," pp. 183, corresponded to the highest part of the corona above the horizon as seen from Cambridge at the time of totality. Drawings oriented in this manner will in the following pages be spoken of as oriented from the vertex. Assumed time of mid-totality $21^{h}. 7^{m}$. Camb. M. T. Sun's axis 21° 14′ to the east of the vertical.

the eastern part was very sensibly broader and brighter than the western. Afterwards they became equal, and some time before the emersion the western side was manifestly broader and brighter than the eastern. His design in attending so diligently to such an observation was this: he thought, as he afterwards told me, that I might desire to note the time of the middle of the obscuration, and being in the same room with me he was willing to assist me in judging of that time, and believed the method which he took to be the properest for it; accordingly I do remember that I heard him call out to me '*Now's the middle*,' though I knew not at that time what he meant. I think this observation of Mr. Walker's is of moment; I have therefore been very particular in giving you the circumstances of it, that you may yourself judge how far it may be depended upon,—for my part I cannot see any reason to doubt of it. Besides this ring, there appeared also rays of a much fainter light in the form of a rectangular cross. I have drawn you a figure which represents it pretty exactly as it appeared to me. The longer and brighter branch of this cross lay very nearly along the ecliptic,* the light of the shorter was so weak that I did not constantly see it. The colour of the light of both



Drawing by an Observer at Cambridge, 1715, May 2nd.

* The above remark shows that the orientation which has been adopted is probably the correct one. It seems probable that the crossing lines were not intended to represent coronal structure, but merely to cut down the length of the shorter arms of the cross.

was the same. I thought it was not so white as that of the ring, even in its fainter parts, but verg'd a little towards the colour of very pale copper. You may observe that in my figure the branches of the cross are represented as bounded by parallel lines, for so they appeared to me. But there are others here who saw a very different form. I have therefore sent you another figure—the most remote of any I have met with from my own. This was drawn by a very ingenious gentleman, representing the appearance as seen by himself. He differs also from me in this particular—viz., that he takes the cross of light to be only a continuation of the ring, whereas I make 'em to be entirely distinct from each other."

Eclipse of 1766, February 9th.

The drawing made by the officers on board the *Comte d'Artois* is somewhat of the same type as that made by Cotes's friend in 1715, a period which may also be described as one of comparative solar inactivity. The rays in the equatorial regions are in both instances given as decidely longer than those in the neighbourhood of the sun's poles: and, having regard to the type of corona which has been observed during more recent periods of solar inactivity, it seems probable that the four cones or pyramids of light did not correspond to four unequal and unsymmetrically placed groups of synclinal structure, but that the smaller cones or groups of rays were intended to represent the polar rays,* and the longer cones corresponded to great groups of coronal structure extending to a great distance from the sun's limb in the equatorial regions. It will be noticed that the equatorial rays are inclined at an angle of some 20° to the position of the solar equator as given in the woodcut; but it is quite possible that such an error in orientation may have been made either in the drawing given by the officers of the ship, or in the copy of it published by LE GENTIL. Possibly, in no instance can an orientation from the vertex be depended upon as being correct within 10°.

* See the remarks with respect to the representation of polar rays on p. 501.

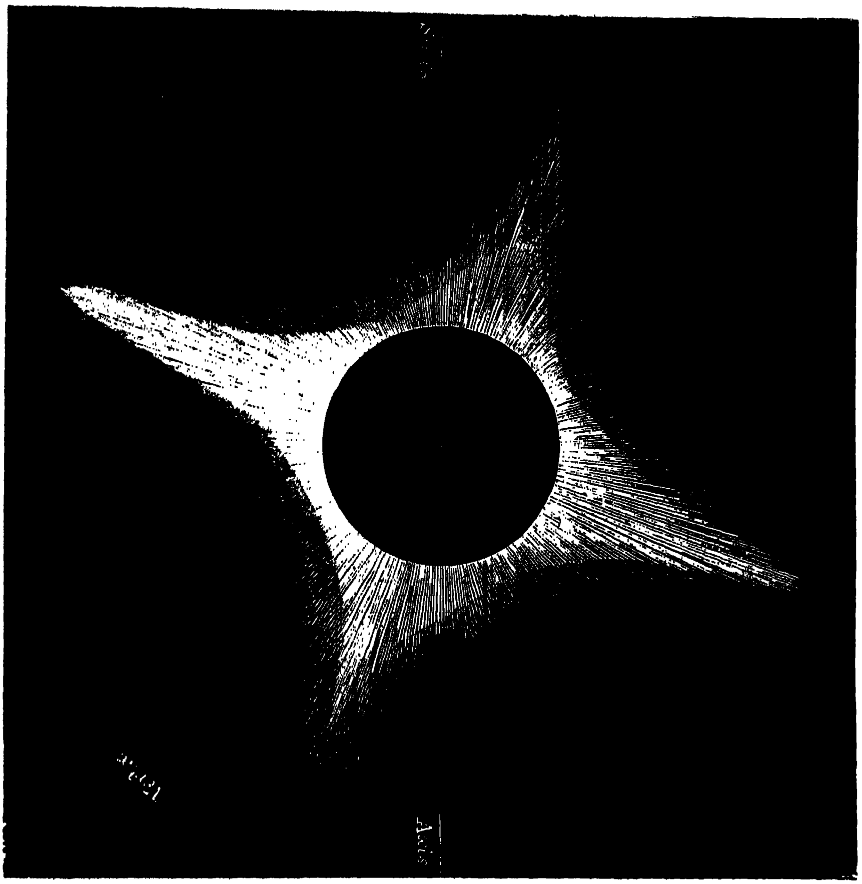
Officers of the Ship "Comte d'Artois."

ON BOARD THE *Comte d'Artois*
9th February, 1766.

"Voyage dans les Mers de l'Inde," par M. Le Gentil. 4°, Paris, 1781.

(p. xvi.) Dans la même planche, on voit en bas l'éclipse totale de Soleil du 9 Février 1766, observée à bord du *Comte d'Artois* par 34° de latitude méridionale, et à 41° 27′ de longitude orientale, méridien de Paris.

During the o security a lu nous circle w obs.rved aLo the moon, wi cones or pyr mids of light two longest c which were t N.E. and S.



Drawing by Officers on board the *Comte d'Artois*, 1766, Feb. 9th.*

Les officiers qui m'ont communiqué cette observation dans un très-grand détail, m'ont assuré qu'ils avoient une très-bonne montre, qu'ils

* The above woodcut has been made from the copper plate given at the end of Le Gentil's second volume. It has been oriented from the vertex on the assumption that the original was a naked-eye picture, and that the south pole of sun's axis was 42° 17′ to the left of the vertical.

réglèrent pendent l'éclipse par deux hauteurs prises à $1^h\ 10^m$ d'intervalle. Je supprime tous ces calculs, et je dirai seulement qu'ils ont observé

Le commencement de l'éclipse à	$2^h\ 34^m\ 0^s$	temps vrai
L'éclipse totale à . . .	$3^h\ 41^m\ 25^s$	,,
Le recouvrement de la lumière à	$3^h\ 42^m\ 18^s$	,,
Et la fin de l'éclipse à . .	$4^h\ 44^m\ 40^s$	,,

Pendant la durée de l'obscurité totale, on aperçut un cercle lumineux autour de la Lune, formant quatre cônes ou pyramides de lumière opposées par leur base; mais dont les deux plus longues étoient dans la direction du Sud-ouest et du Nord-est: ce cercle et ces quatre cônes de lumière, donnèrent assez de clartè pour distinguer, quoiqu'avec peine, l'heure qu'il êtoit aux montres. On vit Vénus fort distinctement, et on auroit sans doute vu plusieurs étoiles, si le ciel n'eût pas été rempli de quantité de nuages.

Eclipse of 1806, June 16th.

M. Jose Joaquin de Ferrer. 73° 52 W. 42° 23′ N. } KINDERHOOK, STATE OF NEW YORK, 16th June, 1806.

"Transactions of the American Philosophical Society," 1st Series, Vol. vi., p. 267.

The disk had round it a ring of illuminated atmosphere; . . . . from the extremity of the ring many rays were projected to more than 3° distance. . . .

With the telescope I distinguished some very slender columns of smoke which issued from the western part of the moon.* The ring appeared concentric with the sun, but the greatest light was in the very edge of the moon, and terminated confusedly at 6′ distance.

* A plate is given at the end of the volume, which appears to be a mere diagram showing the general effect of light observed about the dark moon. The corona is represented within a circular outline with perfectly symmetrical rays diverging in all directions. The slender columns of smoke referred to in the text as issuing from the western parts of the moon are not shown. Assuming the time of mid-totality at Kinderhook to be $0^h\ 49^m\ 47^s$ local true time, the sun's axis would have been 34° 57′ to the west of the vertex,

Eclipse of 1842, July 8th.

Most of the drawings made during this eclipse which have been published appear to be mere diagrams illustrating the general effect observed. BIELA, however, noticed that the corona extended to a great distance from the sun's limb in the eastern equatorial region. He was observing with a telescope with a small field, which did not include the corona in the western equatorial regions, but he mentions that naked-eye observers at Padua saw similar projections of light at both limbs. He also observed some radial structures near the sun's southern pole, which, interpreted by the aid of recent observations, are seen to correspond with the polar rays well observed in 1867, 1871, and 1878.

According to BIELA's drawing and description, the corona appears to have been similar in type to the coronas observed near to the sun-spot minima of 1867 and 1878. It is to be regretted that ARAGO did not publish the drawings of PEYTAL, DALBIEZ, and VILASÉCA, to which he refers.

But little information can be gained as to the brightness of the corona visible during this eclipse from the experiment of MAJOCCHI, as no particulars are given as to the aperture or focal length of the lenses of the daguerreotype apparatus employed, or the diaphragms made use of, or as to the focal length or aperture of the lens with which the light of the corona was condensed upon the sensitive paper. With the small image of the sun given by an ordinary photographic camera, one can easily understand how images of the prominences may have been overlooked.

M. Arago.

42° 41′ 43″ N.
2° 53′ 50″ E. } PERPIGNAN, 8th July, 1842.

"Annuaire pour 1846 du Bureau des Longitudes," p. 322.

En examinant l'auréole à l'œil nu, je vis distinctement, un peu à gauche de la verticale passant par le point culminant de la Lune, une large tache lumineuse formée de jets *entrelacés*. Je donnerai une idée assez exacte de cette apparence insolite, en la comparant à un écheveau de fil en désordre, à un écheveau emmêlé.

M. Arago observed with the naked eye a luminous area to the left of the vertex formed of interlacing jets like a skein of thread in disorder. M. Peytal compared this

structure to a packet of threads of hemp. Drawings by Dalbiez and Vilaséca show curved rays and rays far from radial.

M. l'abbé PEYTAL, de Montpellier, examina avec une attention particulière les traits lumineux dont se composait la couronne, surtout vers la gauche; ces traits parassaient contournés, dit-il, *comme un paquet de filasse de chanvre.* Suivant la figure que M. PEYTAL en a tracée, l'ensemble de ces traits était *presque parallèle* au limbe de la Lune . . . .

(p. 324.) M. DALBIEZ de Perpignan m'a remis un dessin de la couronne très-bien exécuté, où l'on remarque beaucoup de rayons dont les prolongements, loin de passer par le centre de la Lune, sont plutôt tangents au limbe.

Je remarque, enfin, des traits curvilignes bien accusés dans une figure que je dois à la complaisance de M. VILASÉCA, jeune naturaliste très-instruit.

Prof. Majocchi. — 45° 25′ N., 9 10 E. — MILAN, 7th July, 1842.

"Annalen der k. k. Sternwarte in Wien," Neuer Folge, Vol. ii., p. xxxviii.

A few minutes before and after totality an iodized plate was exposed in a camera to the light of the thin crescent, and a distinct image obtained. But another plate exposed to the light of the corona for two minutes during totality, did not show the slightest trace of photographic action. No photographic alteration was caused by the light of the corona condensed by a lens for two minutes during totality on a sheet of paper prepared with bromide of silver.

Wenige Minuten vor und nach der totalen Verfinsterung wurde eine jodirte Platte mit dem Daguerreschen Apparate der Einwirkung des sehr kleinen unbedeckten Theiles der Sonnenscheibe ausgesetzt; in beiden Fällen erhielt man auf der Platte ein deutliches Lichtbild.

Eine andere empfindlichere Platte (preparata con materia acceteratrice) wurde durch zwei Minuten dem Lichte des Silberringes, während der totalen Finsterniss ausgesetzt; man bemerkte nicht die geringste Spur einer Wirkung, obgleich die Empfindlichkeit so gross war, dass bey reflectirtem und selbst bey zerstreutem Sonnenlichte wenige Secunden hinreichen, um auf jener Platte ein Lichtbild zu erzeugen. . . .

Das bromirte Papier, welches eine grössere Empfindlichkeit als die Daguerre'schen Platten besitzt, zeigte die deutlichsten Veränderungen kurz vor und nach der totalen Finsterniss, selbst wenn es nur eine halbe Minute dem Lichte ausgesetzt blieb. Nicht die geringste Veränderung konnte man auf demselben während der totalen Finsterniss wahrnehmen, obgleich es durch volle zwei Minuten dem Lichte ausgesetzt, und dieses Licht noch überdiess durch eine Linse auf dasselbe concentrirt wurde.

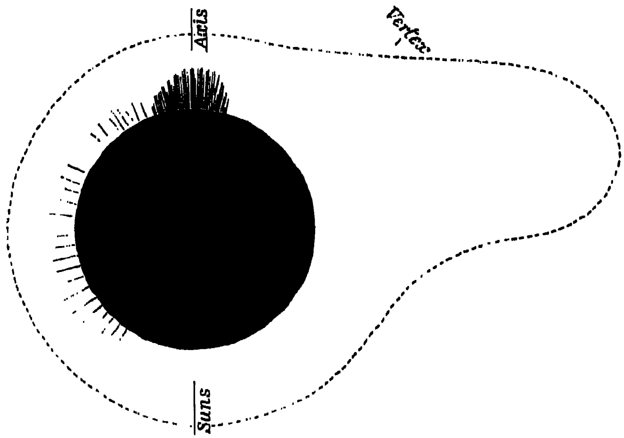
Capt. Biela.

PADUA,
7th July, 1842.

"Annalen der k. k. Sternwarte in Wien," Neuer Folge, Vol. ii., p. xxxv.

Den lichten Ring um den Mond, welcher während der totalen Finsterniss sichtbar war, muss ich für die Sonnenatmosphäre halten, denn rührte selber von einer Mondatmosphäre her, so hätte er wohl breiter und verwaschener sein müssen. Die Fortsetzung des lichten Scheines gegen links unterwärts halte ich für das Zodiakallicht, um so mehr, da die Zuschauer, welche mit blossen Augen beobachteten, diesen lichten Schimmer an beiden entgegengesetzten Seiten der Sonne gesehen haben, ich aber zu beiden Seiten der Sonne nicht beobachten konnte da mein Fernrohr nur etwa anderthalb Sonnenbreiten fasste, und meine Aufmerksamkeit zu sehr an diejenige Seite der Sonne gefesselt war, wo ich die rothen Lichtpyramiden sah.

The light about the moon must belong to the sun's atmosphere. The projection towards the left he considers must correspond to the zodiacal light. Other observers saw a similar projection on the opposite side of the sun, as well as the one seen by Biela.



Biela's drawing of the corona of 1842, July 7th.*

* The above outline woodcut is made from a lithographic plate given in the Annalen of the Wiener Sternwarte. It has been oriented from the vertex. Assumed time of mid-totality $18^h\ 27^m\ 33^s$ Padua M. T. Sun's axis $48^\circ\ 25'$ to the east of the vertical.

Eclipse of 1851, July 28th.

Our knowledge of the corona visible during this eclipse would be but slight if it were not for a daguerreotype picture taken at Königsberg with a telescope of 2·4 inches aperture and 2 ft. 6 in. focal length. The daguerreotype plate has been preserved, and is now at the Strasburg Observatory, in the possession of Professor Winnecke, who lent it to an exhibition of scientific instruments at South Kensington in 1876. Plate II. at the end of the present volume was made from a steel engraving published in vol. xxvi. of the *Königsberger Astronomische Beobachtungen*, but it very fairly represents the corona as shown upon the daguerreotype plate.

In the south-western and south-eastern sections of the corona the lower parts of what appear to be groups of synclinal structure are to be made out, and traces of similar groups are also to be seen in the north-eastern and north-western sections of the corona.

The axes of these groups make angles of about 45° or a little more with the sun's axis, though they are not quite symmetrically situated with respect to it. But the position of the projection of the sun's axis as given in Plate II. must not be entirely relied upon, as it has only been determined upon the assumption that the highest part of the corona in the plate in the *Königsberger Beobachtungen* corresponded to the highest part of the corona above the horizon at the time of the observation, the right and left sides being reversed.

The drawings of the prominences made by the various observers of this eclipse differ so greatly amongst themselves that we must speak with caution as to the correspondence between the prominences shown in the drawings, and those which have registered themselves upon the daguerreotype plate. But in the main it may said that the drawings favour the assumption that the orientation which has been adopted is correct.*

* LITTROW, in the "Astr. Nachr.," vol. xxxiii., p. 132, gives the position of three of the prominences measured from the north point through the east as 111°, 282°, 262°; and there seems little doubt that the crooked prominence referred to by BUSCH as marking the longer diameter of the elliptic outline of the corona corresponded with the great curved prominence figured by most of the observers, and referred to by the ASTRONOMER ROYAL as reminding him of a boomerang.

It is especially worthy of notice that BUSCH, in describing the daguerreotype, speaks of the coronal outline when the photographic image is observed with a lens as hexagonal, as if an equal-sided hexagon with somewhat convex sides were inscribed in an ellipse. This hexagonal outline was again strikingly evident in the sun-spot maximum corona of 1871. The outline of the corona as shown in the 1851 daguerreotype, taken 3·5 years after the sun-spot maximum of 1848·1, seems to be rather more elliptical than that of the photograph of the 1871·9 corona, taken 1·3 year after the maximum of 1870·6.* Outline of the corona.

Most of the drawings of the corona made during this eclipse appear to be mere diagrams intended to illustrate the general effect of light observed around the dark moon. The conoidal form with its base towards the sun described by SWAN may possibly have corresponded to a group of synclinal structure. Its axis, as shown in the plate given in his paper in the Transactions of the Royal Society of Edinburgh, is inclined about 28° to the east of the vertical, while the sun's axis as observed from his station would be about 22° 34° to the west of the vertical, making the axis of the conoidal form about 50° to the east of the north pole of the sun's axis.

M. Broch. 58° 59′ 33·9″ N. / 10° 3′ 52″ E. } FREDERIKSVŒRN, 28th July, 1851.

"Comptes Rendus," xxxviii., p. 297.

Sa largeur était de 6′ 30″, mesurée au sectant par M. le lieutenant HAGERUP. Vers le zénith,† l'auréole, plus étroite, était composée de rayons qui semblaient contournés. Il en était de même dans la partie inférieure, de l'auréole. M. BROCH, orientaliste, qui faisait cette dernier observation, ne savait pas que ces jets entrelacés avaient été observés par ARAGO en 1842 du côté du zénith. The corona was narrower towards the vertex, where it was composed of contorted rays, and there was a similar structure below the moon.

Mr. Swan. 57° 42′ 58″ N. / 11° 56′ 20″ E. } A HILL NEAR GÖTTENBURG, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., pt. 1, p. 74.

The corona was distinctly radiated, and showed no trace of annular

* The relative monthly number of sun spots as given by DR. WOLF in the "Memoirs of the R. A. S.," vol. xliii., p. 209, is 64·2 for July 1851; while for December 1871 it was 98·0.

† The account is written by M. D'ABBADIE. The sun's axis as seen from Frederiksvœrn would be about 22° to the west of the vertical.

structure. The most striking feature it presented was the appearance of brilliant beams of light, which shone out in various directions. They were sharply defined, and brighter than the rest of the corona, and they were visible to some distance beyond its general outline. The most remarkable of these objects was a mass of light of a tolerably regular conoidal form, with its base towards the sun, and the curvature of its sides somewhat concave outwards.*

The Rev. W. R. Dawes. 56° 16′ N. 12° 54′ E. RŒVELSBERG, NEAR ENGELHOLM, 28th July, 1851.

"Memoirs of the R. A. S.," Vol. xxi., pt. 1, p. 89.

The constitution of the corona seemed to be somewhat flocculent, but it was not annular, nor interrupted by radii except towards its border.

Dr. A. L. Busch. 54° 42′ N. 20 31 E. KÖNIGSBERG, 28th July, 1851.

"Königsberger Astronomische Beobachtungen," Vol. xxvi.; "Beobachtungen der totalen Sonnenfinsterniss," p. 13.

A telescope of 2·4 inches aperture and 2½ feet focal length was made use of to photograph the corona. Immediately after the beginning of totality a plate was exposed for 84 seconds in the focus of a telescope of 27 lines aperture. The corona as photographed is elliptical in form, and as seen with a lens the outline appears to be hexagonal. A second plate was exposed, but was spoilt by the returning sunlight.

Das Heliometer der Königsberger Sternwarte war schon längere Zeit vor der totalen Sonnenfinsterniss mehrere male zu den Versuchen angewandt worden, Lichtbilder des Mondes in seinen verschiedenen Phasen zu erhalten. Herr BERKOWSKI, der in seinem Fache als Daguerreotypist zu den geschicktesten Künstlern unserer Stadt gezählt werden darf, und unter dessen besonderen Leitung diese Versuche ausgeführt wurden, kam gern meiner Aufforderung nach alle Vorbereitungen zu treffen, um wo möglich ein Lichtbild von der Corona zu erlangen. Zu diesem Ende wurde, da wegen der von dem Observator Herrn Dr. WICHMANN anzustellenden Beobachtungen das Heliometerfernrohr nicht selbst zu diesem Versuche benutzt werden konnte, ein 2½ füssiges Fernrohr von Fraunhofer von 27 Linien † Oeffnung mit dem Stativ des Heliometers so innigst befestigt, dass es vollkommen an der Drehung um die Stundenaxe Theil nehmen konnte.

* See the steel plate of the corona given with Mr. SWAN's account of his observations, published in the Transactions of the Royal Society of Edinburgh, Vol. xx., part iii., p. 335.

† 27 Paris lines are about equal to 2·4 English inches.

Gleich nach dem Eintritt der Totalität wurde die jodirte Platte dem Lichte der Corona ausgesetzt und blieb 84 Secunden lang stehen, welcher Zeitraum nicht etwa nach Gutdünken angenommen, sondern schon im Voraus von Herrn Berkowski, auf seine Erfahrungen bei den früheren Daguerreotypirungen des Mondes gestützt, als nothwendig angegeben wurde. Der Erfolg hat gezeigt, dass, wenn das Licht einige Secunden mehr order weniger auf die Platte eingewirkt hätte, das Bild vielleich, nicht die ausserordentliche Schärfe und Deutlichkeit erlangt haben würde, welche man jetzt darauf wahrnimmt. . . . .

Der Durchmesser des Mondes hat im Originalbilde nur 0·29 Par. Zoll, dennoch lassen sich die äusserst feinen Lichtabstufungen in der Corona unter der Lupe gesehen mit der grössten Deutlichkeit erkennen. Den Stahlstich in dieser Grösse anzufertigen, und dabei alle nur mit bewaffnetem Auge sichtbare Lichtschattirungen auzugeben, war unausführbar, weshalb für den Stich der Maasstab bedeutend vergrössert werden musste. . . .

In dem Originalbilde nimmt schon das unbewaffnete Auge deutlich wahr, dass dar Licht der Corona nicht concentrisch den schwarzen ganz scharfen Mondrand umgiebt, sondern eine elliptische Form hat, deren grosse Axe in der Richtung der Linie liegt, welche durch die gekrümmte Protuberanz und den Mittelpunkt der Mondscheibe gedacht wird. Mit der Lupe gesehen, tritt die äussere Form der Corona jedoch als ein in einer Ellipse eingeschriebenes, beinahe gleichseitiges Sechseck hervor, dessen Seiten nach dem Mittelpunkte ein wenig convex gekrümmt sind. Das glänzendste Licht der Corona liegt als ein feiner zarter Ring concentrisch um den dunklen Mondrand, von diesem aus wird es allmälig immer schwächer, ohne in dem Grade strahlenförmig zu erscheinen, wie solches mit blossen Augen beobachtet worden ist. Fünf Protuberanzen sind mit Sicherheit auf dem Bilde zu erkennen, zumal wenn man das Daguerreotyp in solche Stellung gegen das Auge bringt, dass die dunkel Mondscheibe hellspiegelnd, die Corona dagegen dunkel erscheint. . . .

(p. 15.) Gleich nachdem die erste Platte entfernt worden war, wurde ein zweite eingesetzt. Nachdem dieselbe kaum 40 bis 45 Secunden dem Lichte der Corona ausgesetzt gewesen war, brach plötzlich das Sonnenlicht hervor.

Eclipse of 1853, Nov. 30th.

The lithographic plate given in MOESTA's Spanish account of the eclipse shows great rays in both the eastern and western equatorial regions.* The extent of the corona in the polar regions appears to have been inconspicuous, and if we accept MOESTA's drawing as accurately representing the corona visible during this eclipse, it must have been of the sun-spot minimum type. The relative monthly number of sun spots for Nov. 1853, as given in Dr. WOLF's table, is 31·4.

Don Carlos Moesta.

22^{m} $12{\cdot}78^{s}$ E. of Santiago. 14° 21′ 21″ S. } PISCO, N. PERU, 30th Nov., 1853.

"Informe sobre las Observaciones hechas durante el Ecliipse Solar."

The northern half of the corona was uniform, while the southern half was composed of a multitude of rays. A large ray about a lunar diameter in length was directed upwards. It was inclined about 20° to the south of the vertical. Another long ray was directed downwards about 10° to the north of the vertical.

(p. 9.) Figurándose por un momento un circulo vertical por el centro de la luna, se dividirá dicho anillo en dos partes, a saber: la una situada al Sur i la otra al Norte del circulo en cuestion. Casi toda la parte septentrional del anillo fué uniforme, la parte opuesta sin embargo se compuso de muchos rayos que salian al parecer del anillo i que todos tenian casi la misma altura con escepcion de dos rayos mui largos. De estos últimos el uno se dirijia hacia arriba, inclinado como unos 20° al Sur del vertical, i segun estimacion, hacia arriba tan largo como el diámetro de la luna; el otro se dirijia del anillo hácia abajo, no diametralmente opuesto al anterior, sino inclinado como 10° al Norte del vertical i un poco mas corto que el primero.

* From Moesta's observations it appears that totality commenced at 3^{h} 32^{m} 15^{s} local mean time, and ended at 3^{h} 35^{m} 14^{s} local mean time, which gives 3^{h} 46^{m} $43{\cdot}5^{s}$ local true time for the time of mid-totality; and taking Santiago as 4^{h} 42^{m} 42^{s} west of Greenwich, the north pole of the sun's axis must have been 76° 6′ to the right of the vertex.

Eclipse of 1858, Sept. 7th.

As observed at Paramagua, at the time of mid-totality the south point of the sun's limb was 23° 5′ to the right of the vertex or highest point of the sun's limb, and the southern pole of the sun's axis was 22° 47′ to the left of the south point, so that the southern pole of the sun's axis nearly coincided with the highest point of the sun's limb above the horizon. In determining the position of the sun's axis we have assumed that the plate given in the "Astr. Nachr." corresponds with the original unoriented drawings, and that the points of the compass marked upon the plate by large letters have been incorrectly placed, and were probably only intended to show that the drawing corresponded to the naked-eye view with the southern limb uppermost, and not to the inverted telescopic image.*

If we may rely on the one drawing of the corona visible during this eclipse, it would appear that there were four well-marked groups of synclinal structure corresponding to four of the "grands groups de rayons formant des cônes," and that the axes of these groups were, speaking roughly, inclined at an angle of 45° to the sun's axis, though the northern synclinal zone seems to have occupied a lower heliographic latitude than the southern synclinal zone.

The general outline of the corona appears to have been approximately circular, and although the eclipse occurred 1·4 year before the sun-spot maximum of 1860·1, the corona must be described as of the sun-spot maximum type. On referring to the table of monthly relative numbers of sun-spots given by WOLF, in the "Mem. R. A. S.," it will be seen that the period of solar inactivity which attained its maximum in 1856·0 had entirely passed away, and that the number of sun-spots was two-thirds as great as during the period of maximum development of 1860·1.† The

* This assumption is confirmed by the description of the parabolic group of rays in the eastern equatorial regions, which is described as "partant du diamètre horizontal de la lune vers l'est," as well as by the fact that the two lower conical groups of rays are described as "également à droite et à gauche de la verticale."

† Dr. Wolf gives the relative monthly number of sun spots for Sept. 1858 as 60·7, and for February 1860, the period of the next sun-spot maximum, as 97·9.

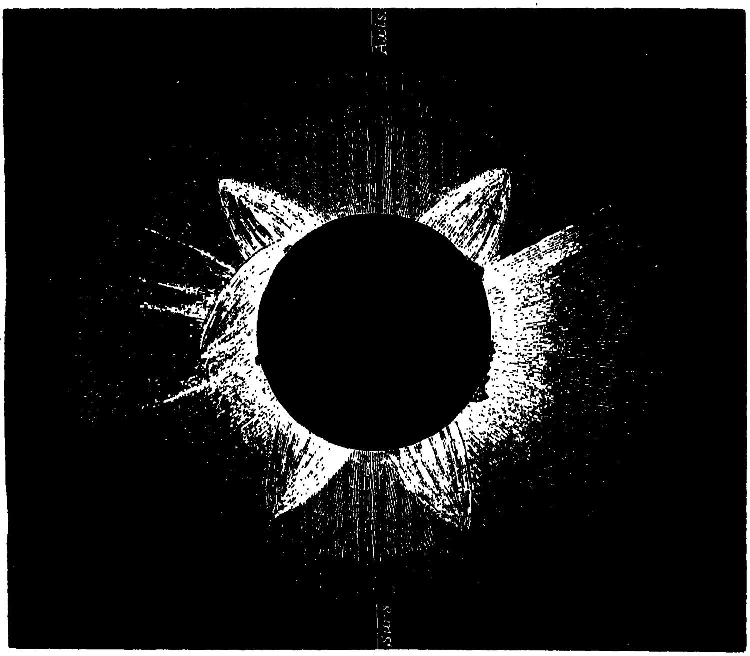
height of the synclinal groups, as measured by LIAIS, 13′, appears to be about equivalent to the height of the denser part of the synclinal groups of the corona of 1871·9.

M. Liais.	25° 30′ 33·24″ S.	PARAMAGUA,
M. d'Oliveira.	48° 26′ 58·59″ W.	
M. d'Azambuja.		
M. de Mello.		
M. de Birto.	25° 30′ S.	PINHEIROS,
M. d'Aranjo.	48° 26′ W.	7th Sept., 1858.

"Astr. Nachr.," Vol. xlix., pp. 285-6.

Corona more than 33′ high. To the naked eye the moon appeared to be surrounded by a narrow band of yellow ight which corresponded to the most luminous part of the corona. Four conical groups of rays were seen by all the observers, both at Paramagua and Pinheiros; according to the measurement of M. Liais they extended to a height of 13′. A fifth very oblique ray was also observed by nearly all the observers crossing the N.E. conical group. The background upon which these rays was seen was, according to Oliveira and Liais, composed of interlacing structure.

Aussitôt après la disparition du dernier point solaire, tous les observateurs ont aperçu la couronne. La disposition qu'elle présentait dans ses rayons était excessivement compliqué, et la courte durée de l'éclipse n'a pas permis à chaque observateur de saisir la totalité des détails. Chacun a concentré son attention sur certaines parties du limbe de la lune, ou sur certains groupes de rayons. Un premier fait parfaitement établi est l'absence d'anneau défini autour de l'astre, absence



Drawing of the corona of 1858, Sept. 7th.*

* Assumed time of mid-totality at Paramagua $11^h\ 3^m\ 4^s$ true solar time. The vertex would be 23° 5′ to the left of the south point, and the sun's axis 22° 47′ to the left of the south point, and therefore the south pole of sun's axis would be only 0° 28′ to the right of the vertex.

remarquée par tous les observateurs de la station central. La couronne présentait une dégradation incessante d'intensité depuis le bord de la lune jusqu'à sa limite. Cette dégradation était rapide à partir du bord de l'astre, au mieux d'une certaine distance du bord de l'astre, et plus lente ensuite. Les limites du fond de la couronne étaient assez mal définies. Dans son ensemble elle formait un cercle dont la largeur à partir du bord de la lune mesurée par M. LIAIS, occupait 28 divisions de sa lunette divisée, ou 33·6′.

Du côté de l'est, cet observateur a remarqué qu'elle pouvait s'étendre 4′ à 5′ plus loin dans le prolongement d'un faisceau de rayons paraboliques qu'il a noté. À l'œil nu la lune semblait entourée d'un filet mince de lumière jaune pâle formant un anneau autour d'elle, mais cette anneau n'était autre que la portion la plus lumineuse de la couronne vue dans la lunette. Sur ce fond lumineux apparaissaient les groupes de rayons qui s'éteignaient longtemps avant d'avoir atteint le bord de ce fond. Ce fond d'ailleurs n'était pas uniforme: il semblait, suivant la remarque des MM. C. B. D'OLIVEIRA et E. LIAIS, être formé d'un entremêlument de rayons de toute nature, et il présentait un pointillé variable et scintillant, comme celui de la surface du soleil sans que toutefois on aperçut sur ce fond aucune raie aussi sombre que le paraissait la surface de la lune.

M. D'AZAMBUJA a remarqué autour de la lune cinq grands groupes de rayons formant des cônes dont la base reposait sur la lune. De ces cinq groupes, deux partaient dans la partie supérieure de l'astre, l'un à droite, l'autre à gauche de la verticale, et deux autres dans la partie inférieure également à droite et à gauche de la verticale. Le cinquième groupe partait à l'est de la lune à l'extrémité du diamètre horizontal. Tous ces rayons avaient cessé longtemps avant d'atteindre l'extrémité du fond lumineux. M. LIAIS a remarqué la même disposition aux rayons coniques, et a mesuré leur longueur à l'aide de sa lunette divisée. Ils occupaient onze divisions de cette lunette ce qui leur donnait 13′ de longeur. D'après M. LIAIS, le rayon de l'est, sur lequel il a spécialement concentré son attention, ne formait pas, comme les quatre autres, un cone normal à la lune, mais il était incliné et recourbé, sa pointe étant dirigée en haut. À sa base il croisait le groupe inférieure de rayons parallèles. Il se projetait ainsi que ce dernier, sur un large groupe parabolique de rayons faibles partant du diamètre horizontal de la lune vers l'est.

M. de Mello, dont la lunette n'embrassait pas le contour entier de la lune, a fait parcourir à son instrument le limbe entier de cet astre, et a noté seulement quatre groups de rayons coniques, mais l'un de ces groupes est à deux pointes, et paraît correspondre au groupe conique vu par M. Liais dans le bas de la lune à l'est, et qui était croisé par le 5^{me} group incliné et recourbé, ce qui lui donnait en effet l'aspect d'un groupe conique à deux pointes. D'après M. d'Azambuja et Liais, les bords de ces groupes coniques étaient courbes et convexes. Cette disposition dans le dessin de M. de Mello est plus spécialement prononcé dans le rayon conique à deux pointes dont nous venons de parler. M. C. B. d'Oliveira a également vu cinq groupes de rayons coniques, et il a remarqué spécialement que la disposition relative de ces rayons pendant toute la durée du phénomène n'a pas varié. La même remarque a été faite par les autres observateurs.

Dans le bas de la lune à l'ouest, un peu au dessus du rayon conique placé de ce côté et près de sa base, partait un faisceau de rayons parallèles, normale au limbe de l'astre. À l'œil nu ce faisceau paraissait comme un rayon large et brillant. Surpassant tous les autres en éclat, ce groupe de rayons était également très remarquable dans la lunette, et était vu comme un groupe étroit de rayons fins et déliés.

Outre ces groupes de rayons principaux, on remarquait beaucoup d'autres rayons normaux au limbe de la lune. M. C. B. d'Oliveira a observé que la lumière nébuleuse du fond de la couronne était plus éclatante par places, formant, pour ainsi dire, des espèces de nuages blancs. M. Liais a noté à gauche assez loin du limbe de l'astre un de ces nuages, ou taches blanches, formé par une réussion de rayons mêlés, mais peu distincts.

À l'île de Pinheiros MM. de Birto et d'Aranjo ont noté huit faisceaux de rayons, dont cinq grands principaux. Ces faisceaux présentent également la forme conique à bords convexes. Ils répondent aux cinq faisceaux coniques de la station principale. Deux d'entre eux sont réunis à la base, et répondent au faisceau à deux pointes de M. Mello. Sur le dessin de M. d'Aranjo, on a remarqué un autre grand faisceau qui répond au faisceau de rayons parallèles, dont nous avons parlé en dernier lieu. Cette disposition de rayons parallèles a été remarquée également à Pinheiros. En somme, l'aspect général de la couronne dans les deux stations paraît avoir été identique.

Les observateurs de l'île de Pinheiros parlent toutefois d'un cercle blanchâtre, qui entourait la lune, et du quel partaient les rayons. Sur le dessin cependant ce cercle n'est pas nettement limité et tout porte à croire qu'il ne s'agit ici que de la partie la plus lumineuse de la couronne que à la station centrale offrait à l'œil nu l'aspect d'un filet doré, et dans la lunette montrait une dégradation incessante d'intensité, toutefois très rapide à une certaine distance de la lune, ce qui dans un coup d'œil, aurait pu faire croire à un anneau.

À Pinheiros, comme à la station centrale, une multitude de petits rayons lumineux émanaient en tous sens normalement du bord de la lune à l'extérieure de cette région plus brillante de la couronne à un ou deux minutes du bord de la lune. À la station centrale il a été nettement remarquée qu'une partie des grands rayons partaient du bord même de la lune. À Campinas, le phénomène a été tellement instantané, et l'atmosphère si peu favorable, que la couronne n'a pu être décrite. . . .

"Sept à huit secondes après le commencement de l'obscurité totale, je fixai mon attention du côté de l'est, sur le faisceau de rayons tangents (le faisceau de rayons coniques recourbé dont la pointe se dirigait en haut, et qui au point de départ partait presque tangentiellement à la lune). Mon attention resta dirigée pendant 15 à 20^s sur ce faisceau et sur une protubérance blanche bordé de noir, près de laquelle il passait, L'un des rayons du faisceau, en particulier, touchait l'extrémité de cette protubérance, et se prolongeant au delà, venait rencontrer la lune à une petite distance, 2° environ. Je vis cette distance s'effacer peu à peu, le rayon restant fixé cependant à l'extrémité de la protubérance, et tranchant par sa vivacité avec la bordure noire de cette dernière. Je vis successivement la partie brillante de la protubérance disparaître derrière la lune, et il resta un très petit point noir, qui disparut environ trois secondes après. Le point de départ sur la lune du rayon, dont j'ai parlé, se trouvait en cet instant précisément à l'endroit où ce point noir, qui ressemblait à la projection d'une montagne luniare, disparut."

M. Liais observed the lunar limb advance and cover up a prominence and part of a tangential ray of the corona on the eastern limb.

Synclinal groups of structure in the S.W. region of the corona.

south-western section of the corona. From a comparison of the photographs and the drawings and descriptions above referred to, it appears that there was a very distinctly marked group of synclinal structure in the south-western section of the corona, and that the axis of the group made an angle of about 45° with the sun's axis.

Observations of Synclinal Structure and Curving Rays in the South-Western Section of the Corona.

(*p.* 537.) Briviesca. **Lespiault** and **Burat** do not give a drawing, but speak of "trois grands faisceaux lumineux juxtaposés. . . . . intérieurement sillonné de traits blancs, qui, s'irradiant à partir du sommet, allaient atteindre les divers points de sa large base."

(*p.* 537.) Pancerbo. **Chevallier** does not give a drawing, but describes "two curved branches issuing from two points of the moon's disc, about 20° from one another, separated much more widely in the middle, and approaching one another at the outward extremity."

(*p.* 538.) Pancerbo. **Wilson** gives a drawing in which the curving together of the rays on both sides of the S.W. group is shown.

(*p.* 542.) Miranda. **W. Beck** describes a remarkable beam which curved away upwards from the S.W. limb.

(*p.* 543.) Miranda. **Weedon** gives a drawing in which rays are shown upon the S.W. limb, curving towards the north.

(*p.* 547.) Near Pobes. **Winnecke** gives a drawing in which there is a large ray on the S.W. limb curving towards the south. In the text he says that he is not sure about the direction of the curvature.

(*p.* 550.) Bilbao. **Lewis** gives a drawing in which there is a conspicuous curved ray on the S.W. limb. In the text he describes it as resembling "a Turkish scimitar."

(*p.* 551.) Near Pobes. **Oom** gives a drawing in which there is a striking ray curving in the same direction as the ray in Lewis's drawing. It evidently corresponds to the southern edge of the S.W. synclinal group shown in other drawings.

(*p.* 555.) Llodio. **Murray** gives a ray curving in the same direction as the curved ray given by Lewis and Oom. He describes it as "about 70° below the eclipse course," and "in shape like a half-crescent."

(*p.* 556.) Near Llodio. **Stronglein** speaks of a horn-shaped ray on the under side, which was curved from left to right.

(*p.* 557.) Vitoria. **Goldschmidt** writes: "Une grande masse lumineuse occupait la partie sud (evidently referring to the vertex as the north),

s'étalant vers le sud-est et sud-ouest en faisceaux courbes concaves vers le sud et entremêlés de masses claires. . . . . . Le faisceau principal au sud-est avait une grande ressemblance avec la branche australe de la Nébuleuse d'Orion."

(*p*. 559.) Vitoria. **Schulz** writes: "Waren sie rechts unten krummlinig und darin eine Lücke."

(*p*. 560.) Vitoria. **Weyer** gives a drawing with some converging lines on the S.W. limb, which he describes in the text as "very fine and distinct," and of a "glossy white." He also gives a ray which would about correspond to the centre of the S.W. synclinal group as seen by other observers.

(*p*. 563.) La Guardia. **Galton** gives a drawing with a great curved ray on the S.W. limb.

(*p*. 564.) Tudela. **R. A. Thompson** describes a beam a few degrees to the west of the lowest point of the sun's vertical diameter, which "appeared to curve upward" as it approached the sun, and "join another beam which was thrown off about 45° below the western edge of the sun."

(*p*. 567.) Valencia. **Wallenberg** gives a diagram with two incurving rays on the S.W. limb, which he describes in the text as "Zwei mit den concaven Seiten gegen einander gekrümmte hakenförmige Lichtstreifen, deren einer mit seinem Ende über den anderen noch etwas hinweggriff, Sie standen am unteren Rande, ihre Ausgangspunkte wenig von einander entfernt, und gaben zusammen das ungefähre Bild einer Ellipse mit geringer Excentricität."

(*p*. 569.) Castellon de la Plana. **Feilitzsch** gives a diagram with a synclinal structure on the S.W. limb, which he describes in the text as "eine leierförmige Ausstrahlung welche in Südwesten stand."

(*p*. 572.) Castellon de la Plana. **Rumker** gives a drawing with a curved ray on the S.W. limb, which he refers to in the text as the "leierförmigen Ausstrahlung."

(*p*. 574.) Desierto de las Palmas. **Secchi** describes an observation of M. Cepeda, who noticed curved rays divided into branches like stags' horns, "vers leur partie supérieure."

(*p*. 575.) Torreblanca. **Tempel** gives a drawing with an elliptic structure on the S.W. limb.

Group of Structure in the South-Eastern Region of the Corona.

The Desierto de las Palmas photographs show very distinctly the southern edge of a mass of brighter structure in the south-eastern section of the corona, at position angle 140° to 130°. Tempel's drawing shows in the same region a remarkable double ray, not quite radial to the sun's limb, and slightly convex towards the sun's axis. On the eastern

Conspicuous group of structure in the S.E. region of the corona.

side of the double ray is a fan-shaped group of rather shorter and fainter rays, all slightly curved in the same direction. WILSON'S drawing shows a long fibrous radial ray in about the same region, with shorter rays on either side, somewhat inclined from the radial towards parallelism with the axis of the longer ray. GALTON'S drawing shows a group of rays, the longest slightly curving towards the south at its outer extremity; and both WALLENBERG and WINNECKE'S drawings show long rays in this region slightly curving towards the south at their outer extremities. Besides the above, the drawings and descriptions of WEEDON, WEILER, OOM, STRONGLEIN, GOLDSCHMIDT, WEYER, R. A. THOMPSON, ARNDT, FEILITZSCH and BULARD, all go to prove that there was a conspicuous group of structure in this region, and that the axis of the group was inclined at an angle of about 45°, or a little more, to the sun's axis.

Observations of a Group of Structure in the South-Eastern Section of the Corona.

(*p.* 538.) Pancerbo. **Wilson** gives a drawing with a long "fibrous" radial ray towards the centre of the S.E. quadrant; the rays on either side of it are inclined from the radial towards parallelism with the axis of the group, and show some traces of synclinal curvature.

(*p.* 543.) Miranda. **Weedon** gives a drawing with a long radial ray with a definite western edge situated decidedly below the centre of the S.E. quadrant.

(*p.* 546.) Near Pobes. **Weiler** gives a drawing with a long radial ray from about the centre of the S.E. quadrant.

(*p.* 547.) Near Pobes. **Winnecke** gives a drawing with a long radial ray curving slightly towards the south, and springing from about the centre of the S.E. quadrant. In the text he says that he had some doubts about the direction of the curvature. It would seem that the "dusky arc" observed by him upon the corona was in the neighbourhood of the base of this ray.

(*p.* 551.) Near Pobes. **Oom** gives a drawing with a long radial ray from about the centre of the S.W. quadrant (position angle 140° measured from the N. point). Its western edge appears rather more definite than its eastern edge.

(*p.* 555.) Near Llodio. **Stronglein** describes a ray more than one-third of the lunar diameter in length, in a position which would about correspond with the centre of the S.E. quadrant.

(*p.* 557.) Vitoria. **Goldschmidt.** From the position of the great curved rays referred to by Goldschmidt, it seems certain that in speaking of the N. point he really refers to the vertex. On this supposition the ray (70° von N.) would have been some 20° above the centre of the S.E. quadrant.

(*p.* 560.) Vitoria. **Weyer** gives a drawing with a great ray from the centre of the S.E. quadrant.

(*p.* 563.) La Guardia. **Galton** gives a drawing with a group of rays from the S.E. quadrant. The longest of the rays curves over at its extremity slightly towards the south, and another smaller ray curves over slightly towards the larger ray.

(*p.* 564.) Tudela. **Thompson** describes a ray considerably longer than the moon's diameter, about 10° below the east side of the sun—that is, a little below the centre of the S.E. quadrant.

(*p.* 567.) Valencia. **Wallenberg** gives a diagram with a long ray from about the centre of the S.E. quadrant; towards its outer end it curves over slightly towards the south: "Eine der Lichtstreifen, die über die Corona hinausragten, war von den übrigen durch seine beträchtliche Länge besonders ausgezeichnet. Er ging vom linken Rande aus, krümmte sich anfangs schwach, gegen sein Ende hin stärker und unregelmässiger nach unten (S)."

(*p.* 568.) Castellon de la Plana. **Arndt.** It is possible that the long ray observed by Arndt may have corresponded to the group of structure in the S.E. quadrant, referred to by so many other observers; but it seems more probable that he was speaking of the unoriented image.

(*p.* 569.) Castellon de la Plana. **Feilitzsch** gives a great ray in the S.E. quadrant, about 90° distant from the synclinal structure in the S.W. quadrant.

(*p.* 575.) Torreblanca. **Tempel** gives a drawing with a conspicuous double ray from about the centre of the S.E. quadrant. It curves slightly away from the sun's axis, and on its eastern side are several other smaller rays all curving in the same direction.

(*p.* 577.) Lambessa. **Bulard** gives a great ray in the S.E. quadrant, about 90° distant from the synclinal structure in the S.W. quadrant.

Group of Structure in the North-Eastern Region of the Corona.

Goldschmidt, after describing a parabolic form which evidently corresponded with the synclinal group in the south-western section of the corona, says that there was a similar though less distinct form on the opposite limb of the moon. Tempel, in his drawing of the corona, gives a broad radial ray springing from about the centre of the north-east

Conspicuous group of structure in the N.E. region of the corona.

quadrant, with slightly incurving rays on either side of it; and WILSON, in his rough sketch of the corona, shows some rays extending slightly beyond the general contour of the corona in this region. From the drawing of BREEN and the description of LESPIAULT and BURAT, it is evident that there were some rays considerably inclined to the radial as well as crossing or interlacing structure in this region, which about corresponded to the vertex of the corona as seen from their stations. GRANT speaks of a long beam a little to the right of the vertex exhibiting decided curvature, and GALTON gives a tangential ray as a striking feature of the part of the corona a little to the left of the vertex.

On the Desierto de las Palmas photographs, the northern edge of a group of somewhat brighter structure is discernible at position angle 20° to 30°. The V-shaped rift to the south seems to be due to a wire, which was stretched in front of the photographic plate to indicate the direction of the equator of the heavens.

In addition to the above evidence, the drawings and observations of WEILER, WINNECKE, WEYER, ROTTENBERG, FEILITZSCH and BULARD, all indicate that there was a bright ray or conspicuous group of structure in the part of the corona opposite to the synclinal structure on the south-west limb.

Observations of Synclinal and Tangential Rays in the North-Eastern Section of the Corona.

(*p.* 533.) Cammesa.	**Breen**	says that at the lower part of the corona, as seen in an inverting telescope (*i.e.* about the centre of the N.E. quadrant), the rays appeared intertwined and entangled.
(*p.* 536.) Breviesca.	**Lespiault** **Burat**	"Aux environs du point zénithal apparent de la lune . . . . on distinguait nettement un grand nombre de traits lumineux d'un blanc plus vif peut-être que les autres, qui, loin de converger vers le centre, coupaient au contraire les rayons et les faisceaux sous diverses incidences, de telle sorte que cette partie de la couronne paraissait formée de lignes de lumière entrecroisées dans tous les sens : quelques-uns d'entre elles étaient même presque tangentes au disque central."
(*p.* 538.) Pancerbo.	**Wilson**	gives a drawing with somewhat longer rays in this region; the outer rays of the group are inclined from the radial towards parallelism with the axis of the group, and show slight synclinal curvature.

(*p*. 546.) Near Pobes. **Weiler** gives a drawing with a pointed ray in the N.E. section of the corona.

(*p*. 547.) Near Pobes. **Winnecke** gives a drawing with a very conspicuous ray in this region of the corona.

(*p*. 557.) Vitoria. **Goldschmidt**, after describing the curved rays of the synclinal group in the S.W. section of the corona, says: "Des apparences analogues se montraient à l'endroit opposé, au nord du disque lunaire, mais moins distinctes, et ayant la forme d'une parabole dont le sommet passait par la Lune."

(*p*. 558.) Vitoria. **Goodwin**. It is possible that Goodwin intended to represent this group of structure by the ray he gives from the N.E. limb.

(*p*. 560.) Vitoria. **Weyer**. Opposite to the fine lines and the short ray corresponding with the synclinal structure on the S.W. limb, Weyer gives a short ray on the N.E. limb.

(*p*. 562.) Sierra de Toloño. **Grant** describes a very long beam which exhibited decided curvature; it was situated a little to the right of the vertex, as seen with the naked eye.

(*p*. 563.) La Guardia. **Galton** gives a drawing with a conspicuous nearly tangential ray springing from the southern part of the N.E. quadrant, and inclined from the radial towards the north. (Compare this ray with the conspicuous tangential ray D γ, in the corona of 1871. Both rays appear to spring from the equatorial side of a synclinal group, and are inclined away from the equatorial regions.)

(*p*. 566.) Valencia. **Rottenberg** refers to "auroral or rather streaky looking branches" extending from the upper limb "something like the clouds called mares' tails."

(*p*. 569.) Castellon de la Plana. **Feilitzsch**. Opposite to the lyre-formed structure corresponding to the synclinal group of rays in the S.W. section of the corona, Feilitzsch gives a conspicuous ray from the N.E. limb.

(*p*. 575.) Torreblanca. **Tempel** gives a drawing with a broad bright ray from the central part of the N.E. quadrant, with smaller rays slightly concave towards it on either side.

(*p*. 577.) Lambessa. **Bulard**. Opposite to the great beam which seems to correspond with the synclinal group in the S.W. section of the corona, Bulard gives a similar beam in the N.E. section.

Group of Rays in the North-Western Section of the Corona.

The Desierto de las Palmas photographs show very distinctly the northern edge of a mass of brighter structure in the north-western section of the corona, at position angle 310° to 320°. GALTON's drawing shows nearly in the same region, but a little more to the north, a

Conspicuous group of structure in the N.W. region of the corona.

group of nearly tangential structure, the rays composing which are inclined away from the sun's axis. In TEMPEL's drawing there is a broad ray with slightly incurving sides about the middle of the north-western quadrant; the smaller rays on either side of it are distinctly inclined from the radial towards parallelism with the axis of the great ray, and curve slightly towards it. From AGUILAR's description, it would seem that there was a striking curved ray in this region.

Having regard to the evidence of the photographs and the above mentioned drawings, as well as to the evidence derivable from the drawings and descriptions of WEILER, WINNECKE, LEWIS, OOM, MURRAY, STRONGLEIN, WEYER, PERRY, FEILITZSCH, and BULARD, it seems probable that there was in this region of the corona a conspicuous group of structure which, if not synclinal in its character, contained curving rays, and rays inclined from the normal to the sun's limb.

Observations of a Group of Rays towards the Centre of the North-Western Quadrant.

(*p.* 546.) Near Pobes. **Weiler** gives a drawing with a broad pointed ray towards the centre of the N.W. quadrant.

(*p.* 547.) Near Pobes. **Winnecke** gives a pointed radial ray towards the centre of the N.W. quadrant.

(*p.* 550.) Bilbao. **Lewis** gives a drawing with rays in almost every direction, and an exceptionally long radial ray a little below the centre of the N.W. quadrant.

(*p.* 551.) Near Pobes. **Oom**, in a carefully finished drawing, gives a short pointed radial ray a little above the centre of the N.W. quadrant.

(*p.* 555.) Llodio. **Murray**, in a diagram-like drawing, gives a narrow radial ray from about the centre of the N.W. quadrant, and a broader ray a little inclined from the radial towards parallelism with the sun's axis, from a more northerly part of the N.W. quadrant.

(*p.* 556.) Llodio. **Stronglein.** The description of a ray "in the upper right-hand quadrant" is rather too indefinite to enable us to identify it with the group of structure referred to by the other observers.

(*p.* 560.) Vitoria. **Weyer** gives a long radial ray from about the centre of the N.W. quadrant.

(*p.* 563.) La Guardia. **Galton** gives a group of structure in the N.W. quadrant. The

	rays are straight or nearly straight, and are inclined from the radial away from the sun's axis. The most northern ray of the group is at its outer edge almost tangential to the moon's limb.
(*p.* 566.) Near Logrono.	**Perry** describes a ray more than 1° in length, which appears to have emanated from a point near to the centre of the N.W. quadrant.
(*p.* 569.) Castellon de la Plana.	**Feilitzsch** gives a radial beam in the N.W. quadrant, about 90° distant from the S.W. quadrant.
(*p.* 574.) Desierto de las Palmas.	**Aguilar** describes a curved ray 40° to the right of the north point—"40° rechts vom Nordpunkte zeigte sich ein Strahl wie ein gekrümmter Baumast."
(*p.* 575.) Torreblanca.	**Tempel** gives a broad ray with slightly curved sides towards the centre of the N.W. quadrant, and smaller rays inclined from the radial and showing slight synclinal curvature on either side of it.
(*p.* 577.) Lambessa.	**Bulard** gives a radial beam in the N.W. quadrant, situated about 90° away from the beam which corresponds with the position of the synclinal structure in the S.E. quadrant.

Rays in the Eastern and Western Equatorial Regions.

Besides the four groups of structure, the evidence with respect to the existence of which we have already examined, there seem to have been conspicuous rays in both the eastern and western equatorial regions. The Desierto de las Palmas photographs show that the light of the corona registered itself upon the photographic plates to about an equal height above the lunar limb in the equatorial regions and in the regions of the four great groups of structure already referred to. The south-eastern group of structure, as shown in the photographs, appears to merge on its northern side with the corona in the eastern equatorial region, and there is but little difference between the height and brightness of the north-eastern and north-western groups and the corona in the adjacent equatorial regions. But the evidence derivable from these photographs only relates to the brightness of the lower part of the corona, extending at most to an altitude of 8′. From the observation of Wilson, it would appear that the brightest parts of the corona corresponded to the south-eastern and south-western groups of structure; and judging by the comparatively few observations of the equatorial rays, it would seem that they did not form

as striking a feature of the corona as the rays composing the groups more to the north and south.

Drawings and Descriptions of Rays in the Eastern Equatorial Region.

(*p.* 535.) Santander. **Thompson.** "The corona appeared on the moon's upper left quarter [*i.e.* on the eastern limb], flashing out in two forks."

(*p.* 546.) Near Pobes. **Weiler** gives a drawing with a long pointed ray in the eastern equatorial region, and a smaller ray to the south of it.

(*p.* 551.) Near Pobes. **Oom** gives a drawing with a short radial ray somewhat above the centre of the eastern equatorial region.

(*p.* 555.) Llodio. **Murray** gives a diagram-like drawing with a very broad radial ray from the eastern equatorial region.

(*p.* 556.) Llodio. **Stronglein's** description of a ray in the upper right quarter [of the unoriented image] is rather indefinite, but he probably refers to a ray from the eastern equatorial region.

(*p.* 557.) Vitoria. **Goldschmidt** describes a ray 70° from the north point (by which he no doubt means the vertex), occupying 30° of the limb towards the north.

(*p.* 565.) Tudela. **R. A. Thompson.** The ray 30° east of the vertex would be a little above the centre of the eastern equatorial region.

(*p.* 575.) Torreblanca. **Tempel** gives a drawing with a fan-shaped group of rays in the eastern equatorial region.

Drawings and Descriptions of Rays in the Western Equatorial Region.

(*p.* 546.) Near Pobes. **Weiler** gives a drawing with a broad-based pointed ray in the western equatorial region.

(*p.* 547.) Near Pobes. **Winnecke** gives a drawing with a small pointed ray just above the centre of the western equatorial region.

(*p.* 551.) Near Pobes. **Oom** gives a drawing with a broad-based ray in the western equatorial region. In his description he speaks of it as "straight, consisting of several beams;—in the middle a longer one, at the sides of which the others diminished in length proportionably to their greater distances from it." According to his measurement of its position, it was situated just about the centre of the western equatorial region.

(*p.* 575.) Torreblanca. **Tempel** gives a drawing with a broad not quite radial ray in the western equatorial region.

Rifts in the Corona.

There is some evidence to prove that there were dark rifts in the corona of 1860, though they do not seem to have been so conspicuous as in the coronas of 1870 and 1871.

A considerable rift in the neighbourhood of the sun's southern pole appears to have attracted the attention of CHEVALLIER and TEMPEL. And it would seem from WINNECKE'S and R. A. THOMPSON'S descriptions, as well as from TEMPEL'S drawing, that there were also dark narrow rifts in other parts of the corona. The "dusky streaks" spoken of by WINNECKE could not have referred to the broad V-shaped rift shown in TEMPEL'S drawing, in the neighbourhood of the southern pole. And the "darker beams" observed by R. A. THOMPSON are described by him as "near to the top of the eastern edge." He is evidently speaking of the unoriented image. In TEMPEL'S drawing there are several narrow dark rifts, which reach nearly down to the moon's limb, and remind one of the narrow rift in the north-eastern section of the corona of 1870, as shown in Mr. BROTHERS' Syracuse photograph (see plate 6), and also of the narrow rifts between the synclinal groups and the structure in the equatorial regions of the corona of 1871 (see plates 7 and 8). Narrow rifts.

Polar rifts.

It is evident, from the Desierto de las Palmas photographs, that the light of the corona of 1860 was less intense in the neighbourhood of the sun's northern as well as of the sun's southern pole. But if we assume that there was a rift in the neighbourhood of the northern pole, it seems probable, from the drawings, that it was more filled up with rays and structure than the southern rift.

Observations referring to Rifts in the Corona of 1860.

(*p.* 538.) Pancerbo. **Chevallier**, after describing the great curved rays of the synclinal group in the S.W. region of the corona, proceeds: "Still further eastward, about 45° from the southern edge [of the unoriented image], the corona was divided by a dark and nearly straight portion, projecting as far as the corona could be traced."

(*p.* 538.) Pancerbo. **Wilson.** [Compare his drawing with that of Tempel.] Besides the shallow part of the corona in the neighbourhood of the sun's southern pole, Wilson evidently refers to a dark space within the S.W. synclinal group.

(*p.* 547.) Near Pobes. **Winnecke** says: "I had also an impression as if there were in the corona dusky streaks." *

(*p.* 565.) Tudela. **R. A. Thompson,** speaking of the corona, says: "I also observed within the halo three darker beams, much shorter than the breadth of the corona. One of these issued from the central point of the crescent I have described [*i.e.* the S.W. group of synclinal structure]. The other two were, I believe, near the top of the eastern edge; but of this I speak from recollection, and not with confidence."

(*p.* 575.) Torreblanca. **Tempel** gives a drawing with a decided gap in the corona in the region of the sun's southern pole.

Lieut. Ashe. 59° 47′ 49″ N. 64° 13′ 15″ W. UNGAVA BAY, LABRADOR, 18th July, 1860.

United States Coast Survey Report for 1860, Appendix 21. Report of Prof. Stephen Alexander.

(p. 19.) In consequence of the clouds, Lieut. Ashe was the only one of the astronomers who caught a sight of the corona.

A bright halo surrounded that part of the moon that he was looking at, and at about 20° in the second quadrant † he saw a white flame shooting up to a considerable distance. His standard of reference was the vertical; he used no screen glass in observing the total immersion.

Through an opening in the clouds the corona was seen on shipboard by the seamen at a position about three-quarters of a mile to the S.W. of our station.

The report of Purser's Steward COLLINS states that "the size of the ring appeared to be about one-third as broad as the dark moon, and of a bright radiant colour, emitting quivering and sparkling beams of light, but uneven in its size and intensity all around."

* In his German report, p. 36, Winnecke says: "Es schienen mir auch dunkle Strahlen, wenn dieser Ausdruck erlaubt ist, darin vorhanden zu sein."

† A diagram has not been constructed to illustrate Lieut. Ashe's observation, as there seems to be some doubt as to what he means by the second quadrant. If he refers to the lower right hand quadrant (image not inverted), and the degrees are measured from above downwards, "the white flame shooting up to a considerable distance at about 20° in the second quadrant" would be at position angle 218°, for at Ungava Bay the north point was about 27° to the east of the vertex, and the sun's axis was consequently rather more than 32° to the east of the vertex. Position angle 218° would about correspond to the position of the curved ray noticed by so many of the observers.

Mr. Breen. 42° 46′ N. } 4° 12′ W. } CAMMESA, NEAR AGUILAR, SPAIN, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

I noticed just above and below the cusps the appearance of a faint light, and the whole of the periphery of the moon which could be seen in the field of view was instantaneously surrounded by a nebulous corona.

The instant the last gleam of sunlight had vanished, the corona burst out in all its magnificence, the faint light which was seen at the extremities of the crescent joining together with the rapidity of lightning.

Breen's drawing of the corona of 1860, July 18th.*

The instant the sun had disappeared, I examined the periphery of the moon with the greatest care and attention for the red prominences; but although I passed round it with the telescope twice in succession, I was unable to perceive the slightest trace of them, and immediately afterwards a dense cumulus cloud passed over, and completely hid the sun and moon for the rest of totality.

The corona appeared slightly yellow close to the moon, and of uniform brightness; but about two minutes' distance from the margin it was of a pearly white, and had a radiating appearance.

The light and radiations of the corona were perceptible for a distance equal to half the diameter of the moon.

* The above woodcut is made from a drawing given in Breen's MS. report. It has been oriented from the vertex. Assumed time of mid-totality $2^h\ 36^m\ 48^s$ local true time. Sun's axis 41° 41′ to the west of the vertex.

Cloud-like appearance in part of corona

At the lower part of the corona (as seen in an inverting telescope) the rays appeared intertwined and entangled, and passing in different directions —giving one the idea of cirrus cloud.

The colour of the moon was of a dark grey, and its surface was not of uniform tint; it seemed of a globular form.

Mr. Buckingham. 42° 46′ N. } 4° 12′ W. } CAMMESA, NEAR AGUILAR, SPAIN, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

Crossing rays: structure like drawn-out silk

Close to the moon the corona appeared an exceedingly faint orange-yellow, but in a very few seconds it became intensely white, and appeared to have very strong rays between the eye and the less white nebulous ground. The rays could only be compared to fine silk drawn out, and extended a full diameter of the moon. Much to my surprise, no coloured prominences were visible. I noticed the rays appeared in two places to cross each other, on the north and eastward.*

Mr. William Wray. 42° 46′ N. } 4° 12′ W. } CAMMESA, NEAR AGUILAR, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

Corona seen for 20 seconds. No curved rays observed.

At the instant of totality, and for twenty seconds afterwards, I saw the corona to perfection. It appeared as an annulus of yellowish-white light, surrounding and in contact with the dark moon, about the sixth of a diameter broad, like a nearly uniform luminous groundwork pierced with innumerable exceedingly fine and closely compressed irradiations, many of which were prolonged outside of the brilliant ring to a very great distance, forming a glory or halo, the rays of which became much fainter and less compressed as they receded from the corona, until, at about two diameters of the moon distant from the limb, they were merged into the deep purple of the sky. The transition from the brilliant and nearly uniform portion to the less compressed, whiter, and much fainter glory, was very rapid; it was not however quite sudden, so that no distinct line of demarcation was

* See TEMPEL's drawing: the great crossing rays in the S.E. section of the corona would as seen from Cammesa, appear to spring from near to the eastern end of the moon's horizontal diameter. The crossing rays "on the north" probably corresponded with the crossing rays observed by BREEN and LESPIAULT and BURAT in the neighbourhood of the vertex.

shown. No curvature was perceived in any of these rays, but a very slight motion due to varying atmospheric refraction was suspected.

Mr. T. C. Janson. 42° 21′ N., 3° 43′ W. BURGOS, 18th July, 1860.

MS. Reports of the 1860 Expeditions.

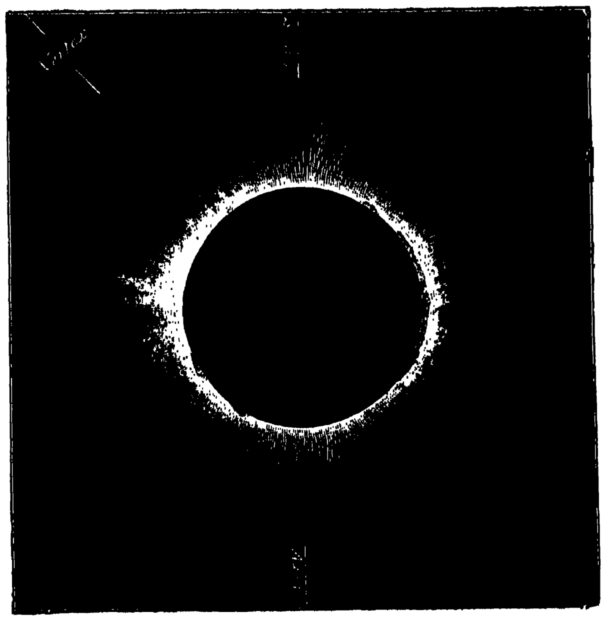
The instant the thin crescent disappeared, a brilliant corona broke forth entirely round the body of the moon. During the latter part of totality I remained gazing at the corona without the telescope. It appeared to increase in brilliancy, and flickered like the aurora borealis—sending out three or four streamers much longer and sickle-shaped. They vanished with the first ray of the returning crescent of the sun. Sickle-shaped streamers.

Commander Thompson. 43° 26′ N., 3° 41′ W. SANTANDER, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The corona appeared on the moon's upper left quarter, flashing out in two forks, the wire* (2) bisecting the lower fork. It extended downwards at irregular distances on the moon's limb, and was of a yellowish colour.

The corona on the right side of the moon also broke on the upper right quarter (just below the wire marked 4) in a fork, but not so large as on the other side. It extended upwards and downwards until it met and mixed with the corona on left side first seen.



Commander Thompson's drawing of the corona of 1860, July 18th.

* Commander Thompson made use of a ship's telescope in which four cross-wires had been placed, dividing the field into segments of 45°. Wire 1, 5, appears to have been placed horizontally; wire 3, 7, vertically; and wires 2, 6, and 4, 8, at 45° to the horizon. The above woodcut has been made from a rough water-colour drawing given in his MS. report. It has been oriented from the vertex. Assumed time of mid-totality $2^{h}\ 37^{m}\ 54^{s}$ local true time. Sun's axis 40° 50′ to the west of the vertex.

M. Lespiault.
M. Burat. 42° 33′ 3″ N. 3° 20′ W. } BRIVIESCA, 18th July, 1860.

Observations sur l'Eclipse Totale du 18 Juillet 1860, par M. Lespiault, Prof. d'Astronomie à la Faculté des Sciences de Bordeaux, et M. Burat, Prof. de Mathematiques au Lycée.—Bordeaux, 1860.

The corona not like the glory round the head of a saint, because the rays are not symmetrical, some of them being radial, while others are grouped in narrow conical bundles, whose bases appear to rest upon the moon; others are curved, especially at their exterior extremity. Special attention is called to the interlacing texture of the region near the vertex; and to three rays situated between 120° and 150° from the vertex toward the W., one of which had an extension of 45′.

(p. 4.) La plupart des relations antérieures comparent l'auréole lumineuse aux gloires dont les peintres environnent les têtes des saints; l'analogie ne nous a pas paru complète: les faisceaux et les traits lumineux, qui rayonnaient autour du disque obscur de la lune, étaient loin d'être disposés avec symétrie, leur éclat, leurs dimensions, leur forme, leur position même par rapport au limbe, étaient variables d'un point à l'autre, et variables sans régularité apparente;—ici, des traits de lumière isolés s'elançaient à peu près dans le prolongement des rayons; là, ils se groupaient en minces faisceaux coniques dont la base s'appuyait sur la lune, tandis que leur sommet allait se perdre dans l'espace par teintes dégradées. Ces jets lumineux, bien que généralement rectilignes, étaient souvent recourbés, surtout vers leur extrémité supérieure; ils partaient presque tous du bord même du disque obscur, et quoique leur multiplicité dans le voisinage du limbe donnât à la portion intérieure de l'auréole un éclat plus considérable que celui de la région extérieure il ne nous a nullement paru que cette auréole dût être considérée comme divisée en deux zones concentriques.

Nous signalons à l'attention des astronomes deux particularités remarquables: aux environs du point zénithal apparent de la lune—c'est-à-dire, dans la région la plus élevée du disque pour une lunette qui ne renversait pas les images—on distinguait nettement un grand nombre de traits lumineux d'un blanc plus vif peut-être que les autres, qui, loin de converger vers le centre, coupaient au contraire les rayons et les faisceaux sous diverses incidences, de telle sorte que cette partie de la couronne paraissait formée de lignes de lumière entrecroisées dans tous les sens: quelques-unes d'entre elles étaient même presque tangentes au disque central.

En descendant vers la droite du disque—c'est-à-dire, vers l'occident—la portion du limbe qui s'étendait du 120° au 150° à partie du zénith, servait de base à trois grands faisceaux lumineux juxtaposés, dont le

dernier particulièrement avait une étendue beaucoup plus grand que les autres parties de l'auréole; sa longueur totale était d'environ trois rayons du disque, ou 45′; il était intérieurement sillonné de traits blancs, qui, s'irradiant à partir du sommet, allaient atteindre les divers points de sa large base; ces traits avaient quelque ressemblance avec ceux d'une aurore boréale, mais leur lueur était plus douce et plus tranquille. Nous ajouterons, sans vouloir tirer de cette coïncidence des conclusions anticipées, que ces trois faisceaux remarquables correspondaient à la région la plus montueuse du disque lunaire.

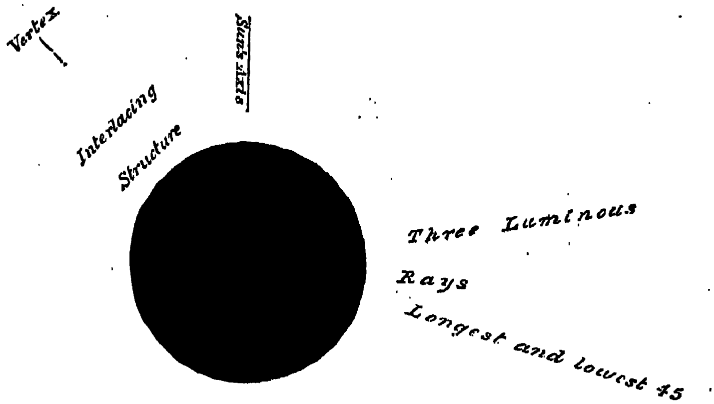


Diagram constructed to illustrate Lespiault and Burat's description of the corona of 1860, July 18th.*

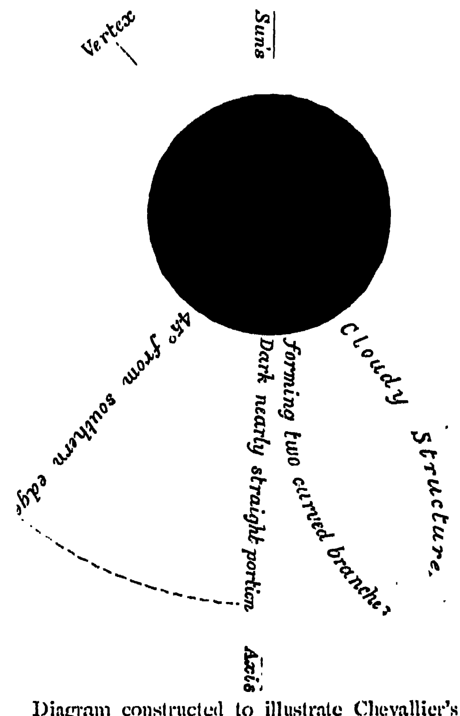


Diagram constructed to illustrate Chevallier's description of the corona of 1860, July 18th.†

Prof. Chevallier.

42° 39′ N. } PANCERBO,
3° 5′ W. } 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The corona was extremely bright, and extended not less than two diameters of the moon beyond the moon's disc. Corona extending 1°, curved rays and cloudy structure.

A little to the east of the lowest part, the corona had a cloudy structure forming two curved branches issuing from two points of the moon's disc, about 20° from

* Assumed time of mid-totality $2^h\ 41^m\ 36^s$ local true time. Sun's axis 42° 30′ to the west of the vertex.

† Assumed time of mid-totality $2^h\ 42^m\ 42^s$ local true time. Sun's axis 42° 27′ to the west of the vertex.

one another, separated much more widely in the middle, and approaching one another at the outward extremity.

Dark rift.

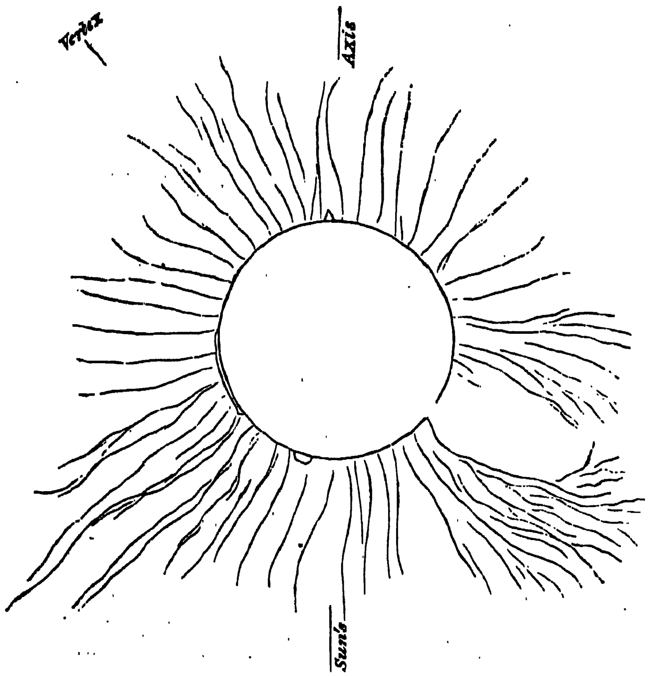
Still further eastward, about 45° from the southern edge, the corona was divided by a dark and nearly straight portion, projecting as far as the corona could be traced.

Mr. J. M. Wilson. 42° 39′ N. 3° 5′ W. PANCERBO, SPAIN, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

Corona extending to two breadths of the moon; in one place a wavy fibrous feather like spun glass, extending to a distance of three diameters; these extensions of the corona were seen to be its brightest parts when viewed through a dark wedge. A gap was also observed through the wedge, but its position is not given.

My telescope, with a magnifying power of 15—20, gave so well-defined an image that I could detect the spots on the sun—7 of them being small. The corona was very brilliant and nearly white, slightly tinged with cream-colour. It extended much farther from the moon's edge than I had anticipated. After some care I estimated that it extended, upon an average, two breadths of the moon at least beyond the edge; and in one place a long, wavy, fibrous feather, reminding me of spun glass, extended, I believe, to three breadths. The whole field of my telescope, about 3° in diameter, was almost filled with corona.



Wilson's drawing of the corona of 1860, July 18th.*

I took up a wedge of coloured glass, and slid it before my eye. The corona was diminished in size gradually; the brightest parts, being

* The above woodcut was made from a pencil drawing still in the possession of Mr. Wilson. It has been oriented from the vertex. Assumed time of mid-totality $2^h\ 42^m\ 42^s$ local true time. Sun's axis 42° 27′ to the west of the vertex.

nearest to the sun, were seen through the thickest parts of the wedge. The corona appeared as a bright ring broken in one place, and having protuberances in two parts, which corresponded exactly with the two long wavy extensions which were visible both in the telescope and to the naked eye.

Article on the Eclipse of 1860, published in the second volume of "The Eagle." *

(p. 184.) The corona was splendid; far exceeding all my anticipations. It was very irregular, in one place near the upper part the light being very feeble, even close by the edge, for an arc of the moon of nearly 10°; the dark part being bounded on one side by straight radii of light; and on the other by similar rays, like fibres of finely spun glass in a brilliant light, which however, at a little distance from the moon, lost their recti- **Wavy structure on west limb.** linear structure, and curved over toward the dark part in fine wavy silky lines. At the part where the sun vanished was a similar wavy portion of the corona (its direction on the whole being nearly radial), which extended from the moon, as well as I could estimate, more than two breadths of the moon.

Mr. Bryne.

42° 20′ N. } 3° 2′ W. } SAN LORENZO MOUNTAIN, EZCARAY, SPAIN, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The ground I selected for observation was 6150 feet above the sea.

Immediately after perfect totality the corona burst into view as suddenly as the unexpected appearance of sheet lightning.

At first a mere narrow rim of brilliant scarlet softened off at **Radiated structure.** its outer edge; it partook of an orange colour as the structure became radiated, like the glory round the heads of saints in pictures. There seemed to be a progressive formation.

Most of the beams which shot out for a length varying from one-sixth to one-third of the moon's diameter were yellowish, and sometimes of a straw colour; whereas others, peering as it were from behind the

* A magazine conducted by members of St. John's College, Cambridge.

former, perhaps of twice their length, and paler still, were softened into a pinkish or purplish white, that blended with the surrounding darkness.

Two rays or prominences.

I remarked two emanations—one at an angle of about 15° from the vertex towards the east, and the second at about 10° towards the west, as seen in an inverting telescope.

The former, which kept in view for about one minute and thirty-five seconds, was curved, apparently steady, and of a bright though delicate orange colour.

As it seemed to proceed from the sun, and to be seen consequently through the corona, its true colour, probably carmine or scarlet, may thus have undergone some modification from being seen through a medium of yellowish shade.

In length it equalled about one-sixth or one-seventh of the sun's diameter.

The other prominence, which kept in view for a shorter period, was smaller, of a much less elongated shape, and of a yellowish burnt-sienna tint.

Mr. G. E. Gavey.

42° 20′ N. 3° 2′ W. — ST. LORENZO MOUNTAIN, NEAR EZCARAY, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The corona was beautifully radiated, and was of a light yellow colour. It had an average width of one-third of the moon's diameter, but many of its bright rays were equal in length to two-thirds of the moon's diameter.

Curved ray.

On the lower and eastern* quarter of the moon, one portion of the rays had the appearance of curving downwards.

Mr. J. Bonomi.

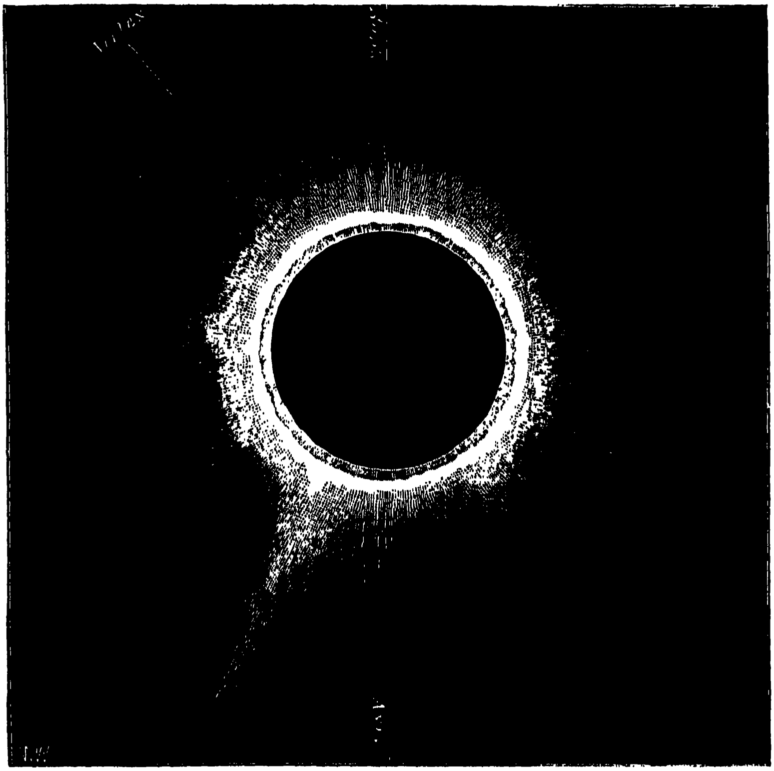
42° 43′ N. 3° 2′ W. — NEAR MIRANDA DE EBRO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

(p. 32 of journal kept by Mr. Bonomi.) White brilliant light all round

* Mr. Gavey probably means lower right-hand quadrant. He used a telescope with an erecting eyepiece.

the sun. Stream of light to the left proceeding from the corona; it seemed to move lower down. There was a band of red light all round the moon's edge.



Bonomi's drawing of the corona of 1860, July 18th.*

Mr. Walter Beck. 42° 43′ N. } 3° 2′ W. } NEAR MIRANDA, SPAIN, 18th July, 1860.

MS. Reports of the Himalaya Expedition, 1860.

For some seconds before the sun was wholly hidden the corona was visible through a lightly shaded glass. It appeared on the side farthest from the crescent of the sun.

In breadth I estimated it roughly at about one-third of the moon's

* The above woodcut was made from a water-colour drawing accompanying Mr. Bonomi's MS. report. It has been oriented from the vertex. Assumed time of totality $2^h\ 43^m\ 18^s$ local true time. Sun's axis 42° 19′ to the west of the vertex.

diameter. Its light was of a dazzling white, so bright as to obliterate the flame of a candle at six inches from the eye.

No annular structure. Curved ray from N.W. structure.

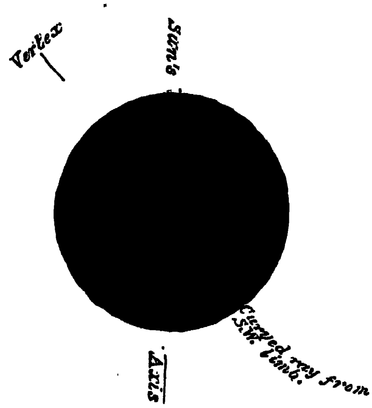


Diagram constructed to illustrate W. Beck's description of the corona of 1860, July 18th.*

As far as I could see, it did not possess an annular structure; on the contrary, it appeared composed of radiating filaments, and possessed of a very remarkable beam, which curved away upwards from the south-western limb of the moon to a length of at least two-thirds of its diameter.

The light was perfectly steady and devoid of flickering.

Mr. R. Winter. — 42° 20′ N., 3° 2′ W. } MOUNTAIN OF SAN LORENZO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The corona consisted of two distinct parts,—that next to the sun being much more regular and intense in luminosity; the outer portion took the form of spiral lines of light radiating in pyramidical forms† from the edge of the inner corona; the inner part was about five-eighths of the moon's diameter in extent, and the outer about one-quarter, making the whole corona about seven-eighths of the moon's diameter in extent. Some of the spiral rays were however longer. The corona retained the same form, and was apparently quite motionless. Our observing station was about 6150 feet above the level of the sea.

Mr. F. M. Weedon. — 42° 43′ N., 2° 59′ W. } HILL NEAR MIRANDA, 18th July, 1860.

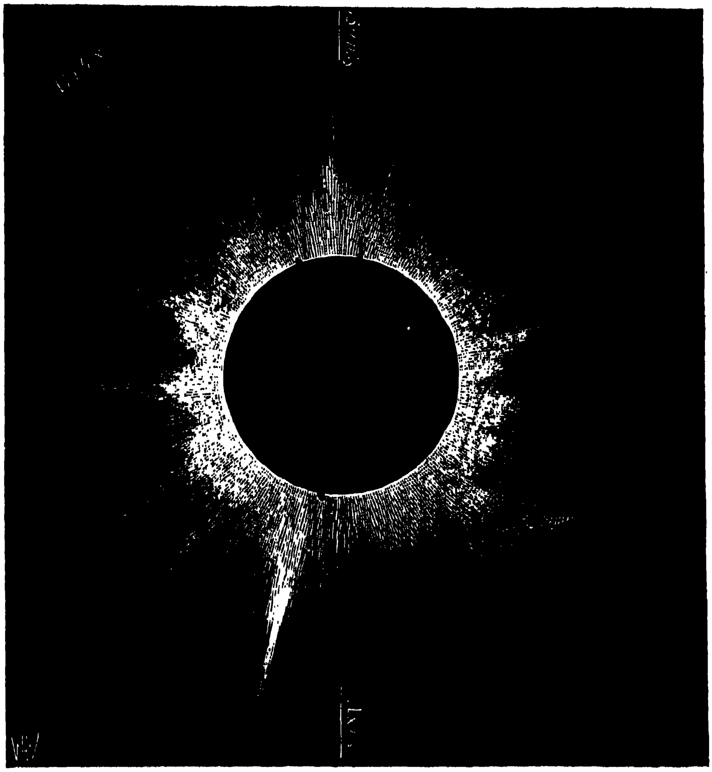
MS. Reports of the Himalaya Expedition.

The corona, to which I particularly directed my attention, extended

* Assumed time of mid-totality $2^h\ 43^m\ 18^s$. Sun's axis 42° 19′ to the west of the vertex.

† Compare this with the account of the conical forms with spiral striæ observed by CLEVELAND ABBÉ in the corona of 1869.

to a breadth on each side of the moon of about a little more than one-half its diameter, as seen by the eye unaided, but there were rays shot out in some places which extended to nearly double this length, while one on the under side, and which I remarked most particularly, was curved towards the side from which the moon approached, and terminated in points, exactly as a jet of vapour would do, if caught at the end by a rapid current of air.



Weedon's drawing of the corona of 1860, July 18th.*

M. Otto Struve.

42° 48′ 2·3″ N. } POBES, SPAIN,
2° 57′ 51″ W. } 18th July, 1860.

MS. Reports of the Himalaya Expedition.

Instrument—A Munich telescope of 2·3 inches aperture and 32 inches focal length, with a power of 44.

A minute and eleven seconds before the commencement of totality I noted that I could well see the contour of the moon on the west side. Shortly before this observation I had removed from the eyepiece the coloured glass I had used until then, as it was my intention to observe all phenomena of the total eclipse without any coloured glass. But here I

* Made from a carefully finished water-colour drawing accompanying Mr. Weedon's MS. report. Assumed time of mid-totality $2^h\ 43^m\ 18^s$ local true time. Sun's axis 42° 19′ to the west of the vertex.

Otto Struve's observation.

made a mistake. Instead of the unprotected aperture, I placed before the eyepiece another glass of very light green colour, such as frequently is used for spectacles. The mistake was not discovered until some minutes after the end of totality. This circumstance must be borne in mind in comparing my observations on the duration of visibility, and on the colour of certain phenomena, with those made by other astronomers.

Cloudy structure seen in corona.

At 47^s before total eclipse I noticed near the uppermost point of the moon (in the inverting telescope), but rather between it and the south pole, some appearances that, just before the sun had entirely disappeared, I supposed to be prominences. But, though in the course of the next few seconds these appearances became considerably more distinct, I doubt much if they ought to be designated by the name of prominences as commonly used; for they wanted entirely that character of rigid form which prominences exhibit commonly, and were very much inferior in splendour to those I saw later, and even to those I recollect to have seen at Lomza in 1851. These appearances looked more like clouds floating in the corona, of which the boundaries were more illuminated than the rest.

The colour of these clouds was greyish-white, and I could not perceive the least trace of red in them, not even in the brightest boundaries. I noticed particularly two groups of clouds, distant from one another about 10° of the moon's circumference. The interval between them was filled with a uniform light, which, however, left the impression as if it was formed by rays coming from behind the moon, and extending in a direction perpendicular to the limb.

On the east side of the preceding group of clouds, the extreme boundary of one of them was more distinct and brighter than the rest. Eleven seconds after the commencement of totality, I estimated the height of this boundary to be 57″. I noted at the same time that this boundary, though curved, had an average inclination to the moon's limb of about 10°. Considering the indistinctness of the former, these estimations can only serve to give a general idea of the height and appearance of this object. I want also to remark that I am not quite sure if the above mentioned boundary, as indicated in the figure, was really in contact with the moon's limb. The general impression remained with me that the cloud was apparently floating in the corona.

Immediately after this estimation had been made I returned again

to the region nearer to the direction of the moon's motion, but I could not perceive there any distinct traces of prominences; though on different places there were clouds similar to those I had just perceived, but of less intensity. Cloudy structure along E. limb.

I also perceived several veins of a livid colour, which extended far into the corona, but could not well be measured, as their forms were not distinct enough for that purpose. Veins extending into the corona.

Extending now the examination of the limb to the regions nearer the north pole, my eye was suddenly struck by the brilliant appearance of a prominence. . . . I have tried to represent the impressions I had of this prominence on a somewhat enlarged scale in the figure.

From its extremities some faint veins extended far into the corona. These veins have also been indicated in my sketch, but with not the least pretension to accuracy, except as to the points where they apparently took their origin. . . . I will add that the corona—or better, the bright background upon which the prominences appeared to project themselves—was very different from what I had seen in 1851 at Lomza. On that earlier occasion the corona was formed of an almost uniform dim light, and was so well defined in its outline that certainly very approximate estimations of the distance of the moon's limb or the prominences from it could have been made. Now, on the contrary, all the corona in the neighbourhood of the moon's limb resembled a chaotic mass of clouds, which gave the impression that the whole mass of light was in an extraordinary state of agitation; besides the clouds, radial rays were predominant in the corona. Corona very different from that of 1851.

Prominence and veins in the corona observed by Otto Struve.

Mr. C. Weiler.

42° 47′ 12″ N. / 2 56′ 13″ W. } Hill of Sta. Marina, 3 miles S.W. of Pobes, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The accompanying sketch is intended to show the outlines of the corona as it appeared to me. The form of the upper left corner impressed itself strongly on my memory.

The rays rising from the red ring in the sketch remained during

Weiler's drawing of the corona of 1860, July 18th.*

the whole of the totality constant in length and form, and showed no movement.

Prof. Winnecke.

42° 47′ 12″ N. } HILL OF STA. MARINA, 3 miles from Pobes,
2° 56′ 13″ W. } 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The corona consisted of short bunches forming together the glory,

* Made from a drawing given in Weiler's MS. report, and oriented from the north point as marked upon the drawing. The sun's axis should be 5° 26′ to the east of the north point. In this woodcut, as well as that on the opposite page, the sun's axis is on the wrong side of the north point.

and five long rays—the length of which were estimated to be from one to one and a half diameters of the moon springing from the glory.

Two of these rays were evidently curved—a fact about which I am quite sure, but about the direction of curvature I have some doubts. **Two curved rays seen.**

The figure is a copy of the sketch which I tried to make on the

Winnecke's drawing of the corona of 1860, July 18th.*

spot, about ten minutes after the end of totality. From this sketch I conclude that the breadth of the ring was 8′, and that of the principal rays 10′. I had also an impression as if there were in the corona dusky streaks.

* Made from a drawing given in Winnecke's MS. report, and oriented from the north point as marked upon the drawing. The sun's axis should be 5° 20′ to the east of the north point.

In the neighbourhood of the prominence which I have marked as (*d*) on the prominence map, I saw a parabolic dusky arc on the light of the corona. . . . . It looked as if it was drawn with sepia on the bright ground of the corona. The position of this arc I cannot give with certainty*—for, according to a preconceived plan, I did not at all attend to telescopic appearances in the corona.

Mr. Warren De La Rue.	42° 43′ 24″ N. } 2° 55′ 20″ W. }	RIVABELLOSA, 18th July, 1860.

Bakerian Lecture published in the "Phil. Trans.," Part i., 1862.

(p. 25.) [The corona] appeared to me to glow with a silvery white light, softening off into a very irregular outline, while from its general boundary shot out several long streamers. It extended generally to about 0·7 or 0·8 of the moon's diameter beyond her periphery. Close to the moon, and reaching not further than 2′, the light was very brilliant, and several zones of gradations of brightness appeared to exist, but the very bright zones would all be comprised in a circle about 0·25 of the moon's diameter. . . .

(p. 30.) In the two coloured drawings, Plates vii. and viii.,† I have

* In Prof. Winnecke's German account of his observations, given in "Les Mémoires de l'Académie Impériale des Sciences de St. Pétersbourg," vii. Série, Tom. iv., No. 1, p. 38, he refers to the dusky arc as being near to a prominence on the S.W. limb. It is shown on the plate of the prominences attached to M. OTTO STRUVE's Eclipse Report, and appears to have been a very faint dusky arc with its convex side towards the sun. According to the position given to it on this plate, it was situated within a few minutes of the sun's limb, in the neighbourhood of the base of the great curved ray from the S.W. limb in Prof. Winnecke's drawing.

Prof. Winnecke's German account of it runs thus:—

"Ich habe noch nachzuholen, dass ich in der Nähe der Protuberanz einen parabolisch gekrümmten, dunklen Bogen im Lichte der Corona erblickte, dessen Form nach einer unmittelbar nach der Totalität entworfenen Skizze auf Taf. 1 in der Nähe der Protuberanz (*d*) wiedergegeben ist. Die dort gezeichnete relative Lage zur Protuberanz ist sehr unsicher, da ich meiner Absicht gemäss auf teleskopische Erscheinungen in der Corona durchaus nicht achtete. Dieser Bogen schien mir gleichsam mit Sepia auf den lichten Grund der Corona gezeichnet zu sein."

† Woodcuts have not been made from the plates above referred to; as they are only given as "fairly resembling" the "general appearance" of the corona, which is depicted with a somewhat quadrilateral outline, the diagonals of which it should be noted correspond with the great groups of structure referred to by so many observers. Some nearly tangential rays are shown in the south-west quadrant, about corresponding with the position of the curving group of rays drawn by other observers. An examination of the prominences shown in the drawings proves that they have been carefully oriented with the north point uppermost.

depicted the result of my telescopic observations; to facilitate my doing which at some future convenient time, I made a coloured sketch on the afternoon of the eclipse. This coloured sketch, the black and white drawings made at the telescope and shown in facsimile in Plate vi., together with my photographs, which I have not hesitated to use to correct any errors of position or dimension in the sketches, have enabled me to give in these drawings what I believe to be a very truthful representation of the appearance of the prominences, immediately after the commencement and just before the end of totality. The corona I do not give as an absolutely true representation of that phenomenon, but as fairly resembling its general appearance. It has been derived from the photographs as far as they show it.

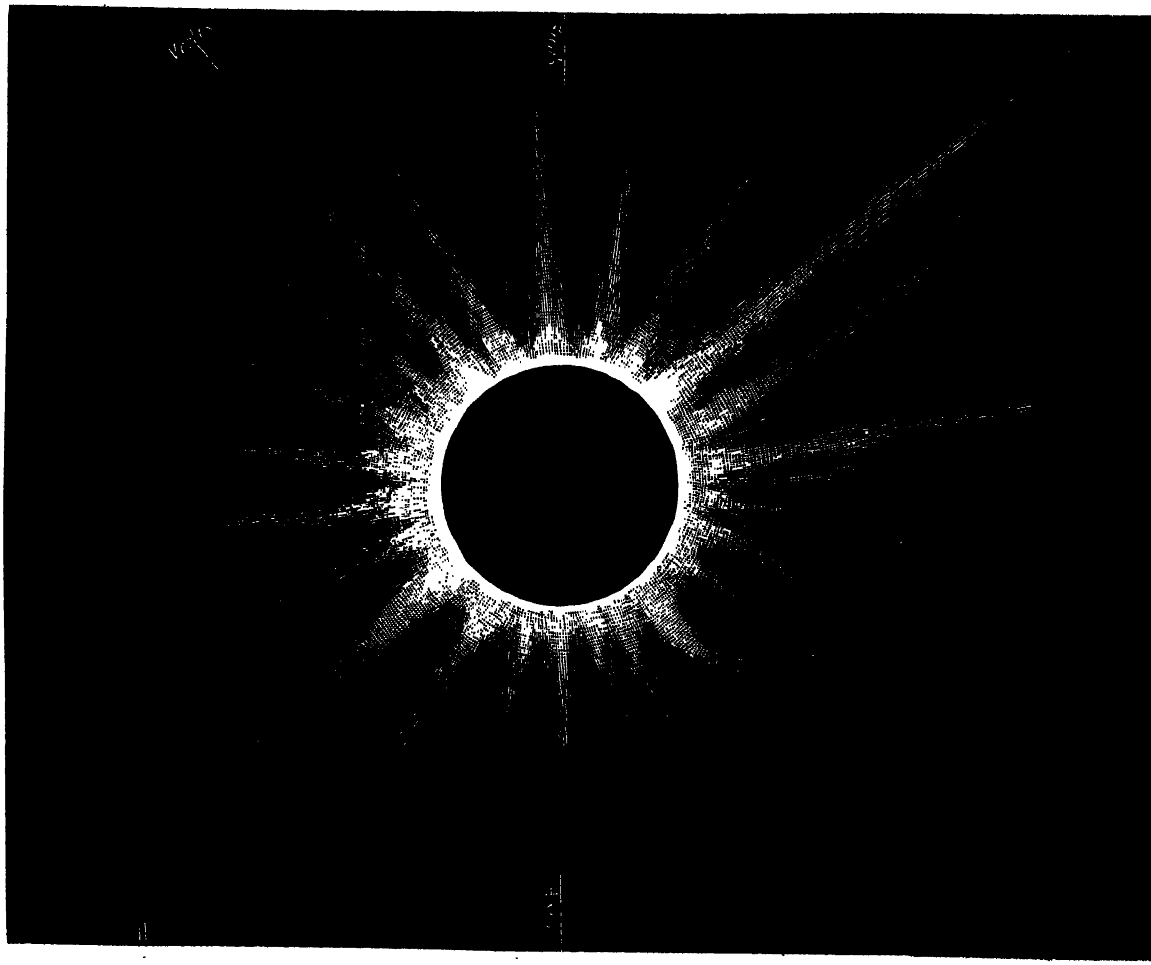
Mr. Wm. J. Lewis. 43° 15′ N., 2° 55′ W. BILBAO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

During the period of totality the sun and moon, and the sky in their neighbourhood, were covered with light fleecy clouds; through which, however, the corona was distinctly visible, and presented the following aspect.

It consisted of a number of distinct rays of different lengths, perpendicular to the moon's circumference, the longest being one which projected horizontally from the left side of the moon (as seen through a reversing glass) the length of which was about 2½ diameters; two or three others were about 1½ diameters long; but the rest were mostly about ⅔rds of a diameter in length. They were nearly all straight, but four or five of those towards the top were more or less bent, especially the one at the very top of the disc, which was very much bent to the left, and resembled a Turkish scimitar. Four or five curved rays.

All the rays remained visible for a second or two after the totality ceased, and then simultaneously faded away, gradually though quickly. While they were visible no flickering or movement of any kind was detected in them. The straight rays remained straight, and the bent ones continued bent the whole time.



Lewis's drawing of the corona of 1860, July 18th.*

Lieut. F. A. Oom. 42° 46′ 44″ N. 2° 53′ 22″ W. ALTO D'URBANEJA, near Pobes, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

Description of instrument.

I was provided with a comet-seeker by Merz of Munich. It was of 3 inches aperture and 25·2 inches focal length, and was mounted on a stand which allowed of nearly equatorial adjustment.

* Made from a water-colour drawing accompanying Lewis's MS. report. Oriented from the vertex. Assumed time of mid-totality $2^h\ 42^m\ 42^s$ local S. T. Sun's axis 41° 36′ to the west of the vertex.

During the totality I made use of an eyepiece magnifying only 8·7 times, and having a field of nearly 6°. In the focus of the first lens of the eyepiece was fixed a micrometer, which consisted of a plane glass-plate on which four concentric circles, intersected by diameters at distances of 22° 30′ from one another, had been cut with a diamond. I had found

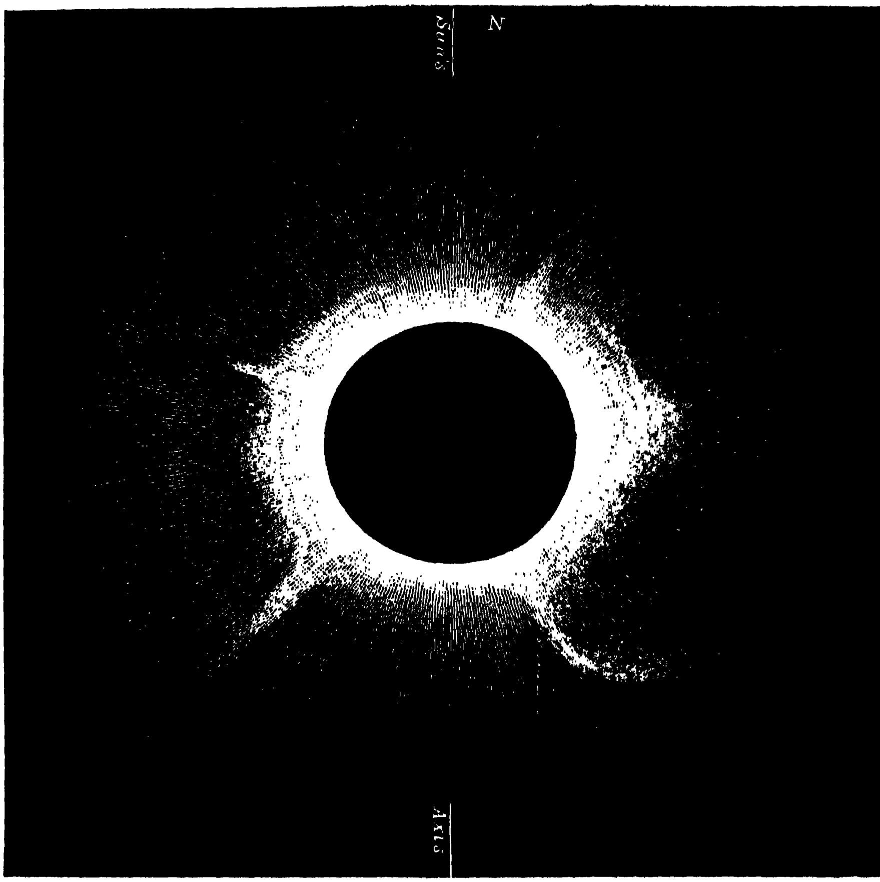


Fig. 1.—Oom's drawing of the corona of 1860, July 18th.*

the following values of the four radii of these circles—viz., 90′·7, 44′·5, 29′·8, 15′·4.

During the totality the corona appeared of a silvery white colour. Description of corona.

* Made from a carefully finished water-colour drawing accompanying Oom's MS. report. Oriented from the north point, as marked upon the drawing. Sun's axis 5° 26′ to the east of the north point.

Lieut. Oom's observation.

Next to the moon's limb there appeared a very bright ring (A, fig. 2), the breadth of which was found to be 2′. It was measured at four points, distant 90° from one another,* and was in each case found to be 2′. The light of this ring was the same at equal distances from the moon's edge, but diminished a little towards its exterior outline, which was very well defined.

From this outline a great many rays of different lengths took their origin; here their light seemed less intense than that of the border of the ring, and it diminished gradually towards their extremities.

All the rays were perpendicular to the ring, and on the whole regularly distributed round its circumference, till at a certain distance from A they could hardly be separated from one another, and formed thereby a second ring B, beyond which their remaining portions could be seen distinctly separated and projecting themselves on the purple-blue sky. For the ring B the measures made at the same four above-mentioned points gave its breadth constantly equal to 3′.

The zone formed by the separated portions of the rays, of which the extremities, though very faint, were pretty well defined, was very irregular in its contour when considered in detail, but on the whole it seemed to be concentric with the moon. The limits of these irregularities, or the shortest and longest distances of the extremities of the rays from the moon's edge, were estimated to be of 7′ and 9′. The outer circles represent these two limits.

Five long rays had their origin at the exterior border of the ring A. Their light mingled itself there with that of the ring, and decreased by degrees towards their extremities, which notwithstanding that were tolerably well defined.

Near their bases they were all perpendicular to that border. These rays were accompanied on their sides and beyond their extremities by masses of a less intense light, visible only towards the ring B, near which I think these masses were about as bright as the border of the ring. They diminished gradually in their intensity with greater distances, both from the ring and the ridges of light (the long rays). Their lateral contours could be made out, their extremities not; they faded away in the

* (*Note by Lieut. Oom.*)—The measures and estimations of the breadths of the rings were made at the points marked 1, 2, 3, 4, in the figure.

sky. The drawing (fig. 1) will give, I think, a better idea of what I have seen than any description can do.

The five long rays are represented in the figure by the numbers I. to V. in the order of their distribution. The measures I obtained for them are the following, in which d represents the distance from their extremities to the moon's edge—and p the position angle referred to the moon's centre and counted from north through east.

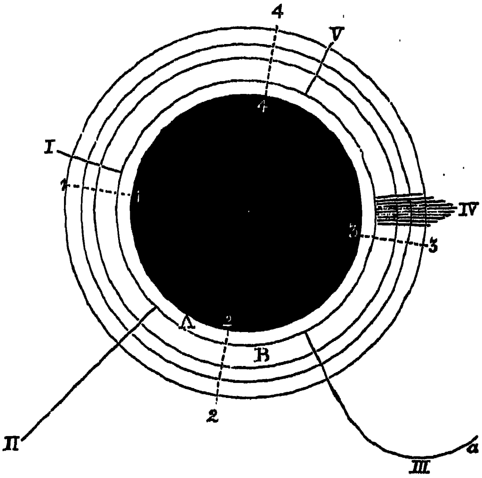


Fig. 2.—Made from a diagram given by Oom.

I. Straight $d = 11'$; $p = 77°$.
II. Straight $d = 28'$; $p = 140°$.
III. Straight till b; for this portion
$d = 13'$; $p = 212°$.
From b bent over towards the west till a; for this point
$d = 28'$; $p = 232°$.
IV. Straight, consisting of several beams. In the middle a longer one, at the sides of which the others diminished in length proportionably to their greater distances from it; for this
$d = 14'$; $p = 277°$.
V. Straight $d = 10'$; $p = 338°$.

After taking a general view of the heavens with my naked eye—during which I noticed that the colour of the sky was brightest near to the corona—I returned to my telescope, and made the following series of measures:—

Breadth of the ring A at the points 1 and 3 $2'$.
Breadth of the ring B at the points 2 and 4 $= 3'$.
Ray II. $p = 140°$.
III. $p = 212°$ at the origin.
IV. $p = 277°$, corresponding to the middle beam.

While I was engaged with the observation of IV. the sun reappeared. The corona diminished suddenly in dimensions and light, but it still maintained for a certain time its general form and structure. About Gradual disappearance of the corona.

Lieut. Oom's observation.

eight seconds later the ring A, and the rays which emerged from it, mixed themselves with the other parts of the corona—which was in this way reduced to a single ring, with excrescences on its border.

The intensity of the corona, which remained concentric with the moon, decreased rapidly, particularly on the side where the sun had reappeared. The above-mentioned excrescences contracted themselves more and more, and disappeared one after another. The last one that was seen corresponded to Ray II.

(*Note by Lieut. Oom.*)—In the account of my observations, I omitted to say that the position angles of the starting-points of the long rays had been measured, not near the ring A, but beyond B. According to this the position angle of III. refers to that part of the ray which was between 5′ and 13′ from the moon's limb.

Mr. E. W. Murray. 43° 7′ N., 2° 50′ W. LLODIO, 18th July, 1860.

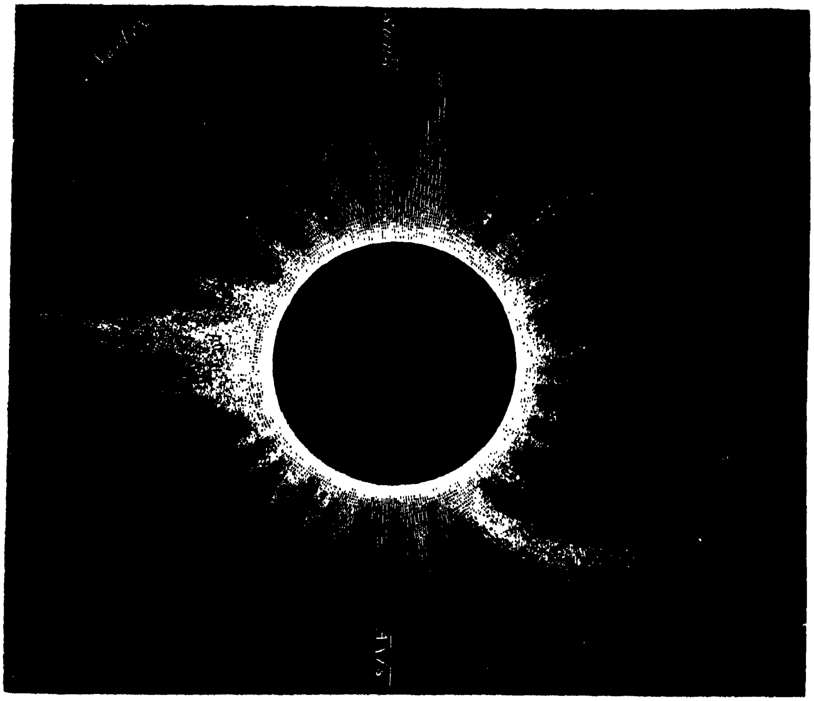
MS. Reports of the Himalaya Expedition.

The corona broke forth suddenly; its rays were steady, and did not shoot up as do those of an aurora. The rays were irregular in their lengths and breadths, but with the exception of one or two they were, I think, on an average ·3 or ·4 of the diameter of the moon.

I could not see them well enough with the naked eye to distinguish whether they were separated into fine rays or not: they consequently bore the appearance to me of being in bunches or pointed tufts, reminding me in shape of the Aiguilles which border the Mer-de-Glace at Chamouni. The two most worthy to be noted were one on the left-hand upper quarter of the moon, about 30° above the line of its course; in length it appeared to be greater or nearly equal to the diameter of the moon, and to be about one-quarter as broad as it was long: the other was from the edge of the lower right-hand quarter, about 70° below the eclipse course: it had about the same length as the first, but was much narrower at its base, and curved to the west, being in shape like a half-crescent. All the rays

Curved ray.

of the corona appeared to radiate at right-angles from the edge of the ring.



Murray's drawing of the corona of 1860, July 18th.*

Mr. John Stronglein. 43° 7′ N. 2° 50′ W. MONTE ARRANA, NEAR LLODIO, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The corona was formed of radiating rays which on an average had a length of ⅓rd the diameter of the moon. Several of them were much longer—and I saw at first in the upper right and left quarter two such rays. A third, still greater, formed itself in the middle of the left hemisphere. Lastly followed on the under side a horn-shaped ray, which Curved ray.

* Made from a rough water-colour drawing accompanying Murray's MS. report. Oriented from the vertex. Assumed time of mid-totality $2^h\ 43^m\ 18^s$ local true time. Sun's axis 41° 50′ to the west of the vertex.

was curved from left to right. The radius of its concavity might have been somewhat greater than the radius of the moon. The two last named were the largest and finest. They had probably a length of $\frac{2}{3}$rds the diameter of the moon, and the width at the base was at least one-fifth the length. These rays during the whole time remained always visible, and kept the same light.

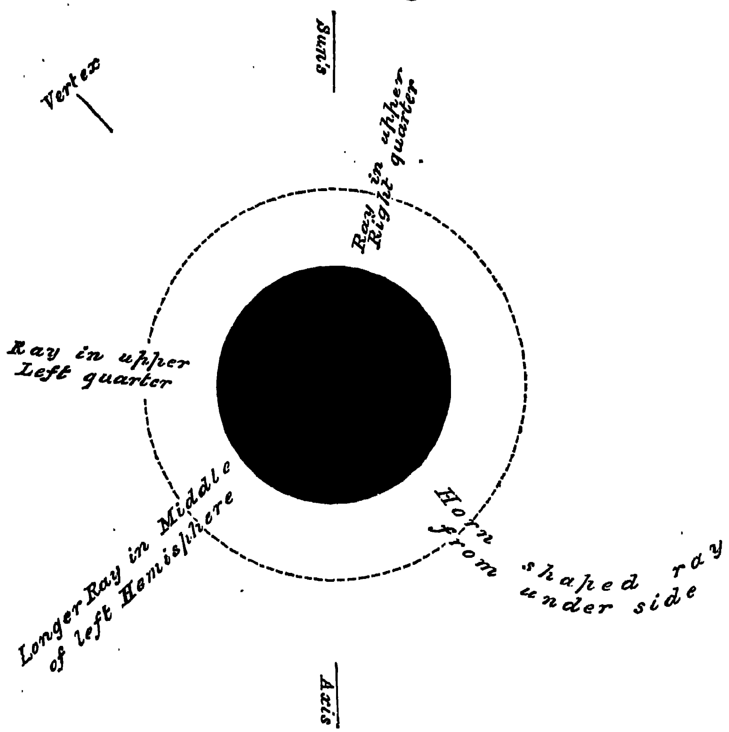


Diagram constructed to illustrate Stronglein's description of the corona of 1860, July 18th.

Herr Hermann Goldschmidt. 42° 50′ 41″ N. 2° 40′ 20″ W. VITORIA, 18th July, 1860.

"Astr. Nachr.," Vol. lvi., pp. 305, 306.

A ray at right angles to the moon's limb 70° from N. was principally remarked. Its base stretched along the moon's limb 30° towards the N. The north-east part was gradually lost in other masses of light. On the southern limb at 170° great curved rays were observed, with masses of light like cirrus clouds on its south-east side. There was also a parabolic

Ich habe hauptsächlich einen Strahl in gerader Richtung, nordöstlich vom Mittelpunkte des Mondes ausgehend, bemerkt (70° von N.), der sich 30° weit am Mondrande gegen Norden verbreitete, ohne jedoch, dass er in seiner ganzen Breite concentrisch nach dem Mittelpunkte unseres Satelliten gerichtet war; der nordöstliche Theil war allmählig in andere Lichtmassen übergegangen. Grosse gekrümmte Lichtstreifen südost und südwestlich, die in 170° auf dem südlichen Mondrand aufstanden, waren nach innen mit einzelnen Lichtflocken an der südöstlichen Seite erfüllt, die

* Assumed time of mid-totality $2^h\ 43^m\ 18^s$ local true time. Sun's axis 41° 50′ to the west of the vertex.

in Form und gelber Farbe den Cirruswölkchen am abendlichen Himmel ähnlich waren; die Hauptform war parabolisch und der südöstliche schwerdtförmige Zweig hatte grosse Ähnlichkeit mit dem südlichen Zweig des Orionschen Nebels. Dieser Gestaltung gegenüber gelegen zeigte sich östlich und westlich vom Mondrande bei 120° und 320° eine parabolische Lichtmasse nach Norden gekrümmt, deren Scheitel ohngefähr durch den Mittelpunkt des Mondes ging und allmählig mit der weniger leuchtenden Masse der Corona gegen Norden verlief.†

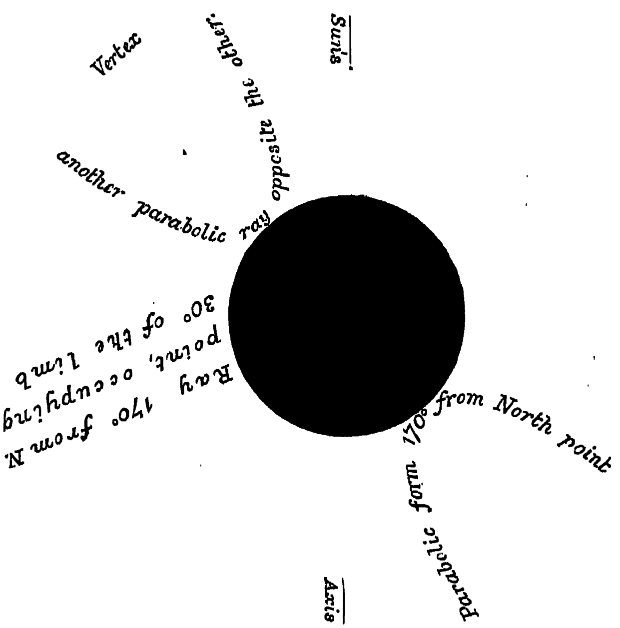


Diagram constructed to illustrate Goldschmidt's description of the corona of 1860, July 18th.*

[The following description of Goldschmidt's observation is given in the "Comptes Rendus," li., p. 266:—

"J'ai principalement remarqué dans la couronne, des rayons partant du centre de la Lune au nord-est, occupant environ 30° de la circonférence et diminuant d'intensité dans la direction nord. Une grand masse lumineuse occupait la partie sud, s'étalant vers le sud-est et sud-ouest en faisceaux courbés concaves vers le sud, et entremêlés de masses claires d'une couleur jaune et de la forme de cirrus. Le faisceau principal au sud-est avait une grande ressemblance avec la branche australe de la Nébuleuse d'Orion.

* Assumed time of mid-totality $2^h\ 44^m\ 36^s$, local true time. Sun's axis 42° 20′ to the west of the vertex.

† We have had some difficulty in determining the meaning of Goldschmidt's description—but the French account makes the latter portion clearer. It seems probable that in speaking of the north point he really refers to the vertex. On this supposition the first ray described probably corresponds with the crossing ray or group of structure forming the eastern boundary of the southern rift, as shown in Tempel's drawing. The parabolic structure at 170° probably corresponds with the group of synclinal structure to the west of the southern rift, shown in so many of the drawings, and the opposite parabolic form to a north-eastern synclinal group.

Goldschmidt's report.

Des apparences analogues se montraient à l'endroit opposé, au nord du disque lunaire, mais moins distinctes et ayant la forme d'une parabole dont le sommet passait par la Lune. La limite de la couronne vue à l'œil nu était plus restreinte; l'anneau qu'elle formait ne dépassait par 6′ d'arc."]

The Rev. H. A. Goodwin. ALI, NEAR VITORIA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The corona commenced in the most striking manner, at the cusps of the disappearing sun, in the form of small tufts, which I could only compare to brushes of electrical light —at first curved, in a direction contrary to the curvature of the sun's disappearing crescent.

Goodwin's drawing of the corona of 1860, July 18th.*

These brushes rapidly grew out, becoming straighter as they lengthened; the upper one approaching very near to a long straight beam which struck out from a point somewhat more easterly on the sun's limb. The corona itself was far from being regular, even at the middle of totality.

Prof. J. H. von Mädler. 42° 50′ 41″ N. 2 40 20″ W. VITORIA, SPAIN, 18th July, 1860.

"Über Totale Sonnenfinsternisse."—Dr. von Mädler, Jena, 1861.

Rays of corona not radial: some of them curved; one nearly tangential.

(p. 12.) Die Corona erschien mir, sowohl im Fernrohr als mit freiem

* Made from a carefully finished water-colour drawing given in Goodwin's MS. report. Oriented from the vertex. Assumed time of mid-totality 2^h 44^m 36^s local true time. Sun's axis 42° 20′ to the west of the vertex.

Ange gesehen, rein weiss. Vielleicht war ein schwacher gelblicher Schimmer vorhanden, doch ich bin seiner nicht gewiss geworden. Sie bestand nicht aus einem unbestimmten Lichtschimmer, sondern die einzelnen Strahlen und Strahlenbündel zeigten eine überaus scharfe und bestimmte Begrenzung. Eine detaillirte Zeichnung war allerdings in den wenigen Momenten nicht möglich, allein ich habe bestimmt wahrgenommen, dass die verschiedenen Strahlen Richtungen nahmen, die durchaus keinem gemeinschaftlichen Centro angehörten. Ich sah mehrere diagonale, ja einige fast normal gegen die übrigen, in unmittelbarer Nähe befindlichen.

Einige gekrümmte Strahlen zeigten sich gleichfalls, und das Ganze liess den bestimmten Eindrück zurück, dass hier kein blosses Inflexionsphänomen vorliege. Nur die Grenze der Corona gegen den schwarzblauen Himmelsgrund war nicht bestimmt, sondern die Strahlen verloren sich allmählich in die Umgebung. Die Ausdehnung (mit freiem Ange gesehen) konnte ich nur beiläufig auf etwa 15 Minuten schätzen d. h. so weit die Strahlen mir noch deutlich erkennbar waren.

Curved ray. This corona no optical delusion.

Herr G. Schulz.

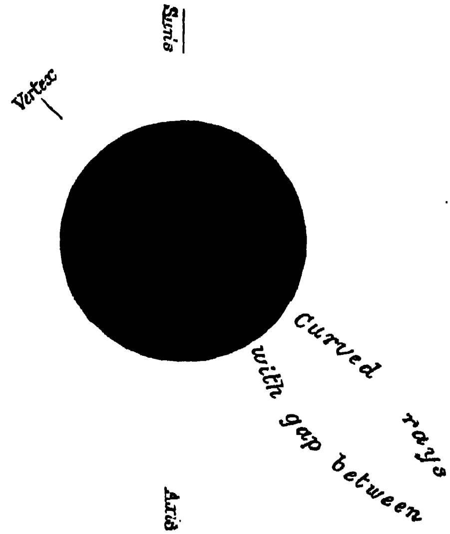


Diagram constructed to illustrate Schulz'* description of the corona of 1860, July 18th.

42° 50′ 41″ N.
2° 40′ 20″ W.
VITORIA, SPAIN,
18th July, 1860.

"Über Totale Sonnenfinsternisse."—Dr. von Mädler, Jena, 1861.

(p. 15.) Während in der Lichtkrone alle übrigen Strahlen geradlinig verliefen und sich hier und da durchkreuzten, waren sie rechts unten krummlinig und darin eine Lücke.

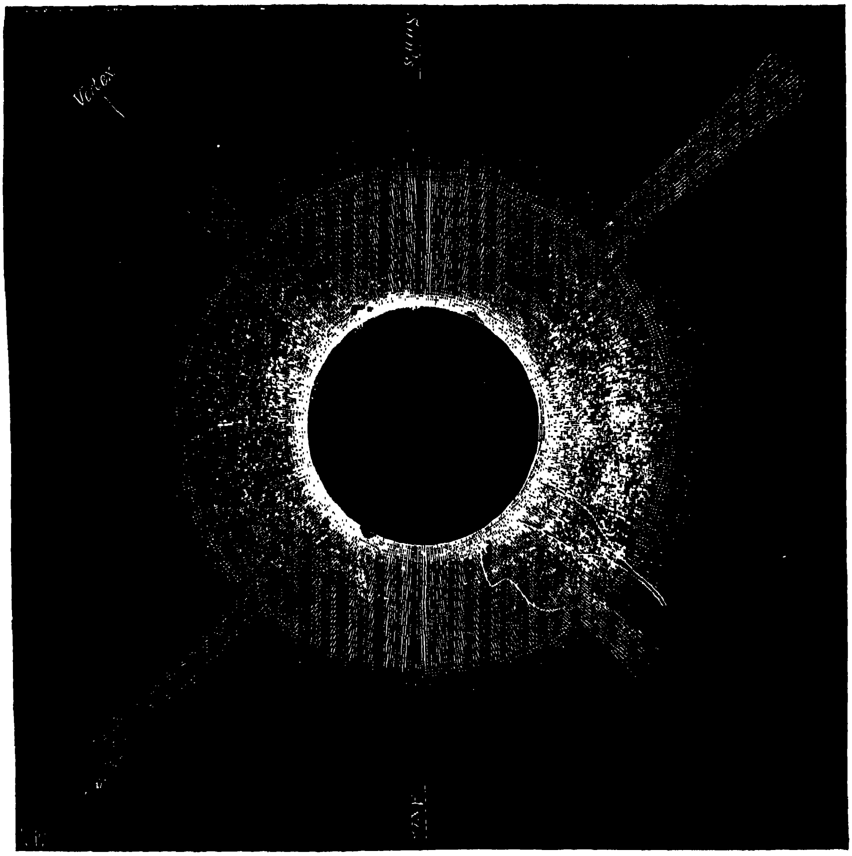
Crossing straight rays, and underneath curved rays, with a void between them.

* Assumed time of mid-totality $2^h\ 44^m\ 36^s$ local true time. Sun's axis 42° 20′ to the west of the vertex.

Prof. G. D. E. Weyer. — 42° 50′ 41″ N., 2° 40′ 20″ W. — VITORIA, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

Looked at without the telescope the corona appeared to me of a light yellow colour, and some longer rays seemed to flash out, especially in the direction of the horizontal diameter on both sides. A smaller ray I



Weyer's drawing of the corona of 1860, July 18th.*

saw below, and the smallest of all at the upper part of the corona. These rays were quite straight, and in the direction from the centre. The

* Made from a drawing accompanying Weyer's MS. report. Oriented from the vertex. Assumed time of mid-totality $2^{h}\ 44^{m}\ 36^{s}$ local true time. Sun's axis 42° 20′ to the west of the vertex.

breadth of the corona seemed to me a little more than the moon's diameter.

Seen through the telescope the corona appeared of a lighter white yellow colour, using no dark or coloured glass. After a first general view of the prominences my attention was involuntarily drawn to the very fine and distinct curved lines at the lower limb (direct image), where no prominences were to be seen. The colour of these lines was a glossy white. I might not call them rays, as they were not straight, neither would I compare them with a "packet of hemp-thread," as M. PEYTAL found them in the eclipse of 1842, at Montpellier, nor did they resemble the regular curvatures as seen by LIAIS in 1858. But perhaps all this belongs to the same object in different forms.

Fine lines in corona.

I took time to draw three of these lines, and well noticed that the one on the left terminated not gradually but suddenly, about a quarter of a degree from the moon's limb. The other two lines extended still further, and nearly joined where they grew fainter, at about half a degree from the limb.

There were no clouds around the sun to which the phenomenon could be attributed, but it was perfectly clear; neither could it lie in the instrument, as several trials afterwards proved.

The Rev. H. A. S. Atwood.

42° 34′ N. } LA GUARDIA, near Logroño,
2° 35′ W. } 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The corona appeared as a ring of brilliant light encircling the dark body of the moon, and radiating from it; the rays appeared to consist of a double set, one placed regularly on the luminous ring surrounding the moon's body, of equal height and on broad bases, in colour not so luminous as the outer rays (which were much longer and very irregular), but of a peculiar attenuated ethereal light—if we may so call it. . . .

This inner equiangular set of rays I noticed very particularly with a well defining telescope having a large field, and about 23 magnifying power; and I am particular in naming it, as I have not met with any of my brother observers who saw it so distinctly.

Prof. Grant.

42° 38′ N. } SIERRA DE TOLONO,
2° 40′ W. } 18th July, 1860.

MS. Reports of the Himalaya Expedition.

The breadth of the corona appeared to be equal to about a fourth of the moon's diameter. From its exterior margin there issued forth diverging beams of light of unequal length. These beams were not of uniform brightness throughout their whole extent. At their junction with the corona they appeared to be of equal brightness with the latter, but from thence they gradually faded off until they were finally lost in the dark ground of the heavens; their average length was about 30′.

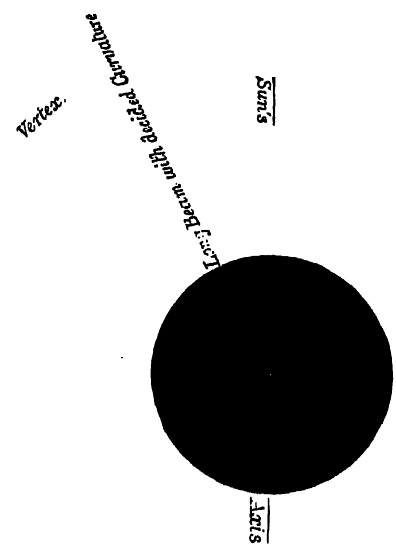


Diagram constructed to illustrate Grant's description of the corona of 1860, July 18th.*

Long curved ray to the right of the vertex.

One very long beam, a little to the right of the vertex, exhibited a decided curvature. The exterior margin of the corona was very imperfectly defined. A similar remark applied to the terminating sides of the diverging beams of light.

The light, both of the corona and of the beams issuing from it, appeared to me to be perfectly motionless. The above-mentioned features of the corona were observed with my naked eye, and not in the inverting telescope.

Mr. Francis Galton.

42° 34′ N. } HILL OF LA GUARDIA, SPAIN,
2° 35′ W. } 18th July, 1860.

MS. Reports of the Himalaya Expedition.

"Totality" came on in great beauty. The corona rapidly formed itself in full distinctness. It did not appear to me to *grow*, but rather to start ready formed into light as the brilliancy of the sun became masked;

* Assumed time of mid-totality $2^{h}\ 44^{m}\ 54^{s}$ local true time. Sun's axis 42° 41′ to the west of the vertex.

however, I speak with doubt upon the point. The drawing is developed from a rough sketch made about one minute after the commencement of totality, and it is to my mind a fair though very weak representation of the general appearance of the corona. I do not know to what I can justly compare that magnificent meteor. It differed from other objects in the remarkable whiteness and purity of its light, and also in the definition of

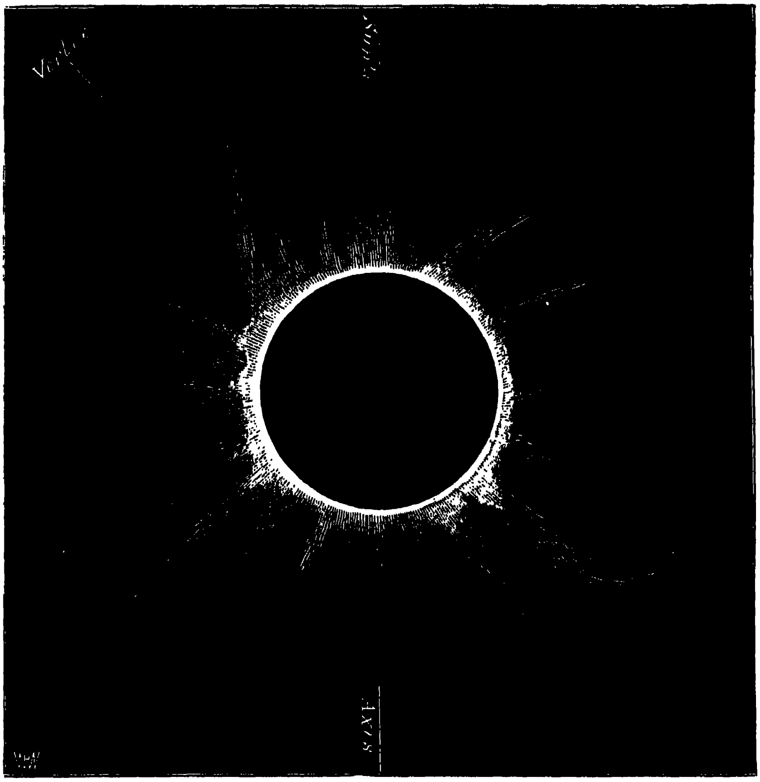


Fig. 1.—Galton's drawing of the corona of 1860, July 18th.*

its shape, as combined with a peculiar tenderness of outline. The rays *a*, *b*, *c*, *d* were especially noted.

References to the diagram on next page.

a and *b* are tangents to the moon's disc; *c* and *d* are curved.

The facts I particularly observed in reference to the corona, are—

1st. The long arms of light did not invariably extend as rays from

* Made from a water-colour drawing accompanying Galton's MS. report. Oriented from the vertex. Assumed time of mid-totality $2^h\ 45^m\ 24^s$ local true time. Sun's axis 42° 49′ to the west of the vertex.

Francis Galton's report.

the centre of the sun. They generally did so, but some were more or less *tangential* to its disc.

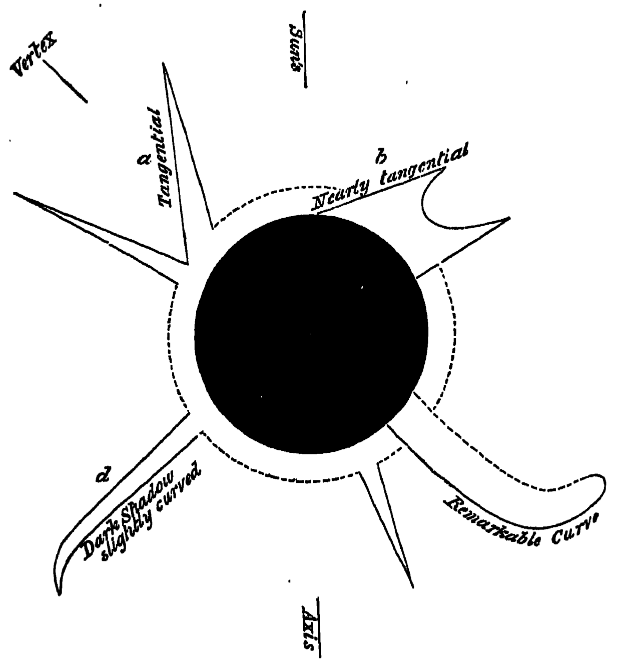


Fig. 2.—Made from a diagram given by Francis Galton.

2nd. The arms were not always bounded by straight lines; some were curved, and the lowermost one was remarkably so.

3rd. The shape of the corona seemed pretty constant in its main features, though its smaller details varied continuously by a gradual diorama-like change. But I cannot be sure that there were any changes, other than those which might be ascribed to growing and waning brightness, and definition. There was no pulsation or other peculiar movement visible to me in the light of the corona.

The Rev. R. A. Thompson. 42° 9′ N. 1° 38′ W. } TUDELA, 18th July, 1860.

"The English Churchman," 26th July, 1860.

I now looked at the corona: it was not of uniform breadth, but generally about half the moon's diameter, while long beams of light issued forth in several directions. The longest, about 10 degrees below the east side of the sun, was considerably longer than the moon's diameter, if I can trust my memory, after the totality was passed.

The beam next in length was not far from the lowest point of the sun's vertical diameter, a few degrees to the west; and this beam, as it approached the sun, appeared to curve upwards, and to join another beam, which was thrown off about 45 degrees below the western edge of the

sun. For a few moments these two beams formed a distinct crescent, with its convex edge nearly touching the sun, otherwise the beams remained unchanged during the whole eclipse; but this crescent was not evident during the whole time.*

Another of the longer beams was thrown off from a point about 30° east of the top of the vertical diameter.

I also observed within the halo three darker beams, much shorter than the breadth of the corona. One of these issued from the central Dark beams in corona.

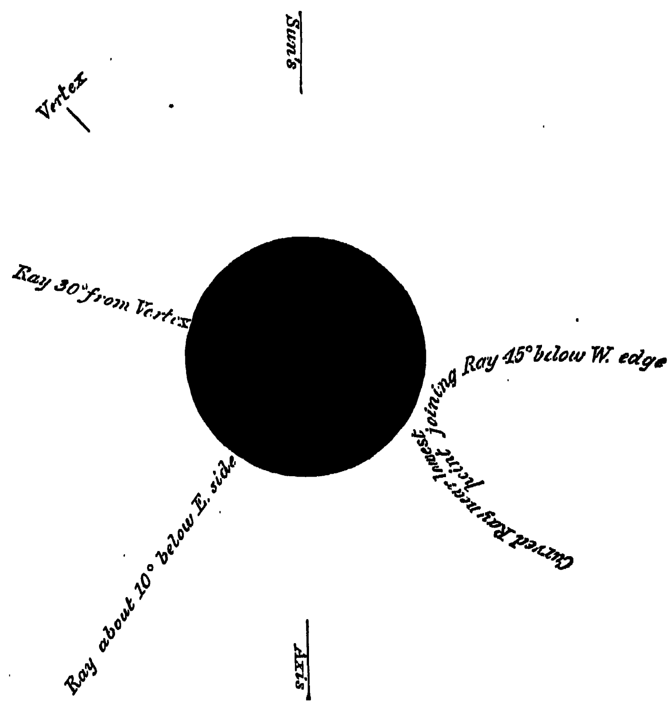


Diagram constructed to illustrate R. A. Thompson's description of the corona of 1860, July 18th.†

point of the crescent I have described. The other two were, I believe, near the top of the eastern edge; but of this I speak from recollection and not with confidence.

* The motion of the moon would tend to uncover the bright matter at the base of the curved rays, and it is possible that irradiation from the bright area may, as totality advanced, have obliterated the details which were at first visible in the higher parts of the corona.

† Assumed time of mid-totality $2^h\ 50^m\ 36^s$ local true time. Sun's axis 43°·45′ to the west of the vertex.

Mr. J. G. Perry. 42° 27′ N. } 2° 30′ W. } HILL OF CANTABRIA, near Logroño, 18th July, 1860.

MS. Reports of the Himalaya Expedition.

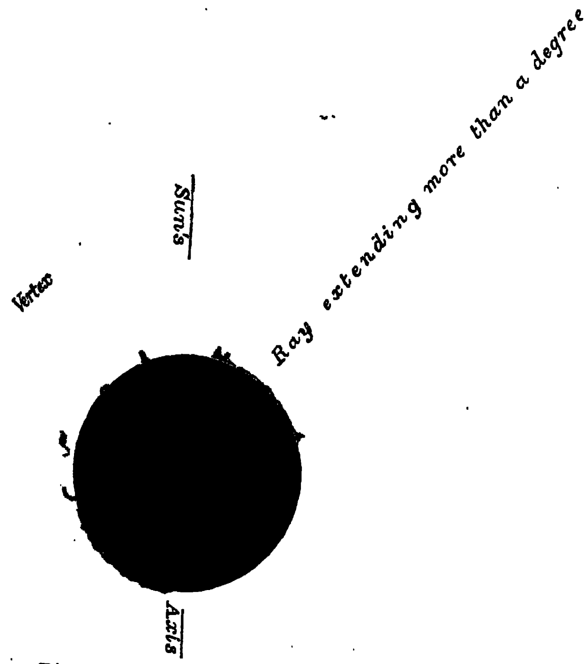


Diagram constructed to illustrate Perry's description of the corona of 1860, July 18th.†

The white light of the corona exceeded in purity anything I had ever seen before, especially in a circle immediately surrounding the moon—where it was less transparent. and probably on that account more white than in the rest of its extent.

Its light was not uniform but radiating. One ray was apparently longer than the rest, and was more than 1° in length. It seemed to emanate from a point coinciding with the middle of the long low red prominence * on the west side.

Baron de Rottenberg. 39° 30′ N. } 3° 50′ W. } VALENCIA, 18th July, 1860.

MS. Observations of the Himalaya Expedition.

The corona was of a pearly or rather cream-like white colour, with auroral or rather streaky-looking branches of greyish colour extending from the upper limb, and to the right, something like the clouds called mares' tails.

* The position of the prominences as given in the above diagram has been taken from a coloured drawing given in Mr. Perry's report sent to the Astronomer Royal.

† Assumed time of mid-totality $2^h\ 46^m\ 3^s$ local true time. Sun's axis 43° 3′ to the west of the vertex.

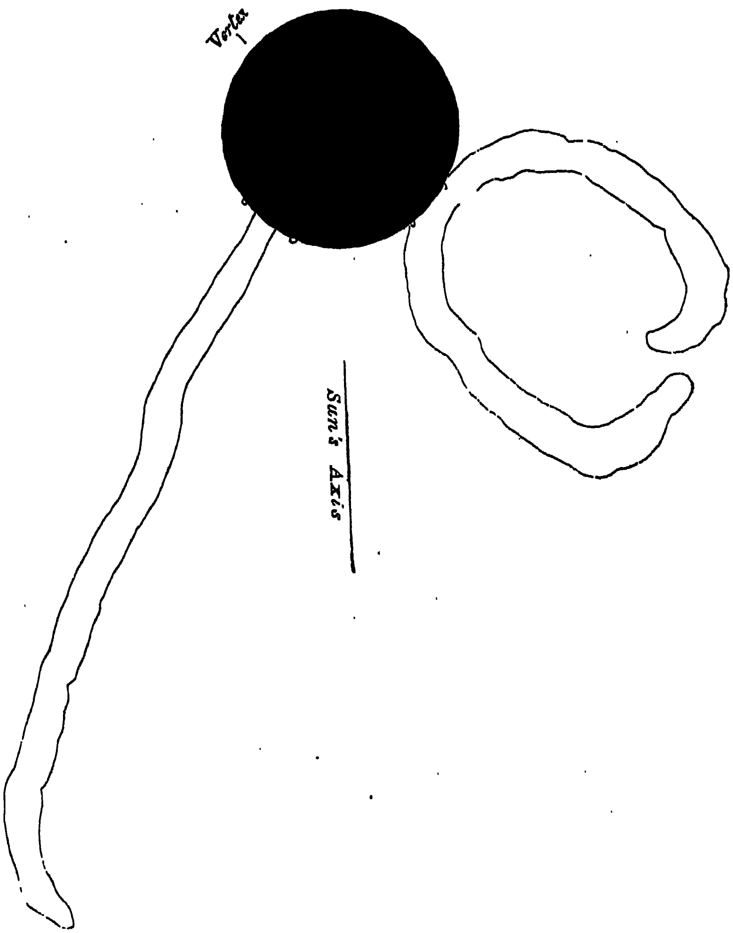
Dr. Carl von Wallenberg.

39° 30′ N. } VALENCIA,
0° 50′ W. } 18th July, 1860.

"Astr. Nachr.," Vol. liv., p. 69.

Einer der Lichtstreifen, die über die Corona hinausragten, war vor den übrigen durch seine beträchtliche Länge besonders ausgezeichnet. Er ging vom linken Rande aus, krümmte sich anfangs schwach, gegen sein Ende hin stärker und unregelmässiger nach unten (S) und liess sich mit Rücksicht auf Helligkeit, so wie auch Weichheit und Gestaltung seiner Umrisse mit einem leichten Wolkenstreif vergleichen. Seine Länge habe ich mit dem Monddurchmesser verglichen und sie dreimal so gross gefunden. Ohne diese Schätzung vorgenommen zu haben, hätte ich die Dimension nachträglich kleiner angegeben. Die Richtung und Gestalt dieses ausgezeichneten Streifens wurde während der Erscheinung selbst im Skizzenbuch angedeutet.

On the S.E. limb a long ray slightly curving towards the S. was seen. Its length was about three diameters of the moon. But the most remarkable form consisted of two curved rays, concave towards each other, from the lower limb.



Wallenberg's drawing, illustrating his description of the corona of 1860, July 18th.*

* The above woodcut is made from a smaller diagram given in the "Astr. Nachr." It has been oriented from the vertex. Assumed time of mid-totality $2^h\ 57^m\ 42^s$ local true time. Sun's axis 48° 15′ to the west of the vertex.

Wallenberg's report.

Ohne Zweifel die auffallendste Form zeigten zwei mit den concaven Seiten gegen einander gekrümmte hakenförmige Lichtstreifen, deren einer mit seinem Ende über den anderen noch etwas hinweggriff. Sie standen am unteren Rande, ihre Ausgangspunkte wenig von einander entfernt, und gaben zusammen das ungefähre Bild einer Ellipse mit geringer Excentricität. Als ich noch eben beschäftigt war, ihre Gestalt auf dem Papiere zu fixiren, brach der erste Sonnenstrahl hervor.

Herr Arndt. 39° 57′ N. 0° 4′ W. CASTELLON DE LA PLANA, 18th July, 1860.

Bericht von Dr. C. BREMIKER aus dem "Monatsbericht der Königl. Akademie der Wissenschaften zu Berlin" für den November, 1860.

Long crossing ray to the S.E. continually changing.

(p. 14.) Die Corona erschien während der ganzen Dauer der totalen Finsterniss in milchweissem Lichte.—Herr Arndt beobachtete dieselbe mit einem fünfmal vergrössernden Galileischen Fernrohre und bemerkte einen etwa 10° langen vom Mondrande nach Südost ausgehenden und verschiedene sich öfters kreuzende Lichtstreifen.

Dr. von Feilitzsch. 39° 57′ N. 0° 4′ W. CASTELLON DE LA PLANA, 18th July, 1860.

"Astr. Nachr.," Vol. liv., p. 86.

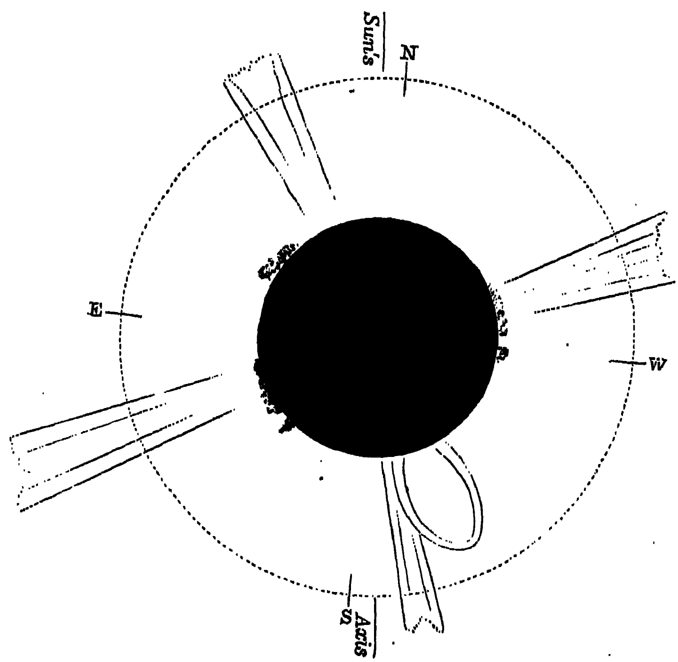
Corona first seen 20 seconds before totality. A lyre-formed structure was conspicuous to the S.W., with a short radial ray beside it. The space on the inside of the lyre was brighter than on the outside. To the S.E. there was another radial ray at least 30′ long. A third shorter ray was present in the N.E.

Die Krone war, nach einem flüchtigen Blick zu urtheilen schon ungefähr 20 Secunden vor dem Verschwinden des letzten Sonnenstrahles gebildet. Ob sie noch längere Zeit nach dem Wiederauftreten des Sonnenlichtes sichtbar gewesen sein mag, kann ich nicht behaupten. Sie war von milchweisser Farbe, wie sich bei dem gesättigten Himmelblau der südlichen Atmosphäre nicht anders erwarten liess. Sie verlief vom Mondrande aus allmälig in das umgebende Dunkel und hatte abgesehen von den Ausstrahlungen eine Breite welche etwa dem Mondhalbmesser gleichkam, und eher grösser als kleiner geschätzt werden konnte. Ein Wallen oder Zittern oder Flimmern, wie es 1842 mehrfach beschrieben wurde, habe ich nicht an derselben bemerkt, ebenso wenig eine koncentrische Theilung.

Vor Allem fiel mir eine leierförmige Ausstrahlung in die Augen,

welche in Südwesten stand und eine kurze radiale Ausstrahlung zur Seite hatte. Der Raum innerhalb der Leier war heller als der ausserhalb. Der radiale Strahl scheint zu Anfang der Finsterniss noch nicht vorhanden gewesen zu sein, indem er sich auf einer Zeichnung des Herrn ARNDT, die gleich nach dem Beginn der Totalität skizzirt wurde, nich vorfindet. Eine andere radiale Ausstrahlung ging nach Südosten und hatte mindestens die Länge des Monddurchmessers. Eine dritte kürzere befand sich in Nordosten. Die Ausstrahlung in Nordwesten endlich ist nicht von mir selbst, sondern von Herrn CLAROS gesehen worden, woraus ich schliesse, dass sie sich erst gegen Ende der Finsterniss gebildet haben mag, obschon Herr CLAROS hierüber keine nähere Auskunft geben konnte.

Dr. Feilitzsch's report.



Drawing made by Feilitzsch, embodying rays observed by Claros in the corona of 1860, July 18th.*

Prof. E. Plantamour. 39° 57′ N. } 0° 4′ W. } CASTELLON DE LA PLANA, 18th July, 1860.

"Observation de l'Eclipse Totale de Soleil du 18 Juillet 1860, par M. le Professeur E. Plantamour."—Genève, 1860.

J'ai essayé de représenter dans la figure I. les phénomènes tels que je les ai vus dans la lunette qui renverse, presque immédiatement après le commencement de l'éclipse totale. Le disque de la lune était entouré d'une couronne d'un blanc assez éclatant et d'une largeur égale au demi-

Figure 1 represents the corona as seen in an inverting telescope soon after the commencement of totality. Figure 3 the corona as seen shortly before the end of totality.

* Oriented from the north point as marked by Feilitzsch. Sun's axis 5° 26′ to the east of north point.

Plantamour's report.

rayon de cet astre environ; elle se terminait à l'extérieur par les rayons, un peu comme la gloire que les peintres représentent autour de la tête des saints. De la couronne partaient trois faisceaux de rayons blancs sous les angles de position de 45°, 105°, et 135°, comptes à partie du nord vers l'est; j'ai estimé leur longueur égale à un diamètre de la lune; le dernier de ces faisceaux était notablement plus large que les deux autres.

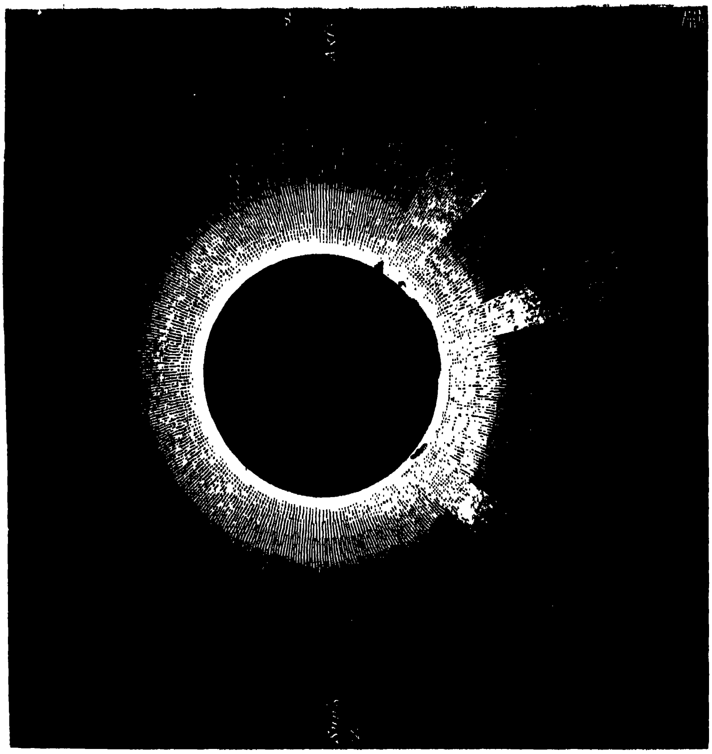


Fig. 1.—Plantamour's drawing of the corona of 1860, July 18th, made at the beginning of totality.*

Au milieu de l'éclipse (voyez la figure II.)† la couronne avait sensiblement la même apparence; les faisceaux de rayons blancs dans la partie orientale de la couronne étaient encore visibles, mais ils avaient diminué notablement d'éclat et de longueur.

* Oriented from the north point, as marked by Plantamour. The sun's axis has by mistake been placed on the wrong side of the north point.

† It has not been thought necessary to have a woodcut made from Figure 2. It may be described as a combination of Figures 1 and 3, except that only two of the rays are given on the eastern side and only three on the western.

Peu avant la fin de l'éclipse totale (voyez la figure III.), de la region nord-ouest de la couronne partaient cinq faisceaux de rayons blancs, aussi longs et aussi brillants que ceux qui avaient paru au bord oriental au commencement de l'éclipse, et qui avaient maintenant disparu: Plantamour's report.

Fig. 3.—Plantamour's drawing of the corona of 1860, July 18th, made towards the end of totality.

Herr Geo. Rumker. 39° 57′ N. 0° 4′ W. CASTELLON DE LA PLANA, 18th July, 1860.

"Die Totale Sonnenfinsterniss am 18 Juli, 1860." 4°, Hamburgh, 1861.

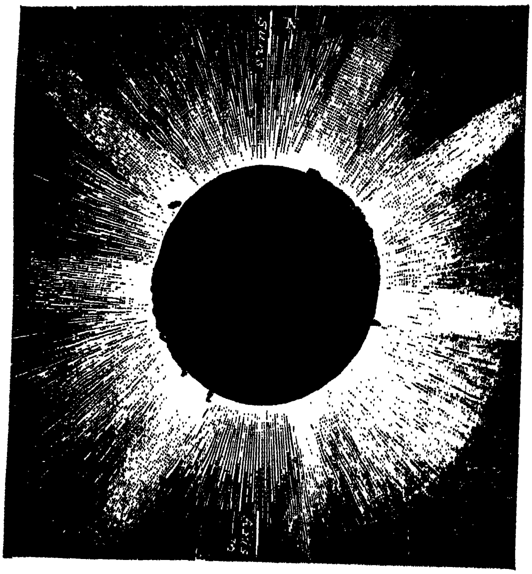
(p. 7.) Der Mond glich jetzt einer glänzenddunklen Scheibe, aus der nach allen Richtungen hin in verwirrender Zahl convergirende blendende goldigweisse zum Theil etwas gekrümmte Strahlen hervorschossen, doch was die Ostseite, wo soeben der letzte Sonnenblick verschwunden war, diejenige Stelle, an der die Corona am hellsten glänzte und die meisten

The moon was surrounded by converging rays, some of them curved. The corona, at the beginning of totality, was brightest on the east side, but towards the end on the west; about the middle of the eclipse, a curved ray was observed to the south.

George Rumker's report.

Strahlen aussendete; unter diesen einzelne grössere gradlinige, welche vielleicht eine Länge gleich der des 3-fachen Mond-Halbmessers erreichten.

(p. 9.) Genau im Westen zeigte sich gegen Mitte der Finsterniss ein grösserer Strahl der Corona, dem vorhin im Osten gesehenen gerade entgegengesetzt. Während der östliche Glanz der Corona sich jetzt immer mehr verlor, nahm in der letzten halben Minute der westliche Theil besonders dort, wo die Wiederkehr der Sonne erwartet wurde, desto mehr an Helligkeit zu, und es schossen immer neue Strahlenbündel hervor, deren Anzahl von Herrn Plantamour zuletzt zu 4 angegeben wird.



Rumker's drawing of the corona of 1860, July 18th.†

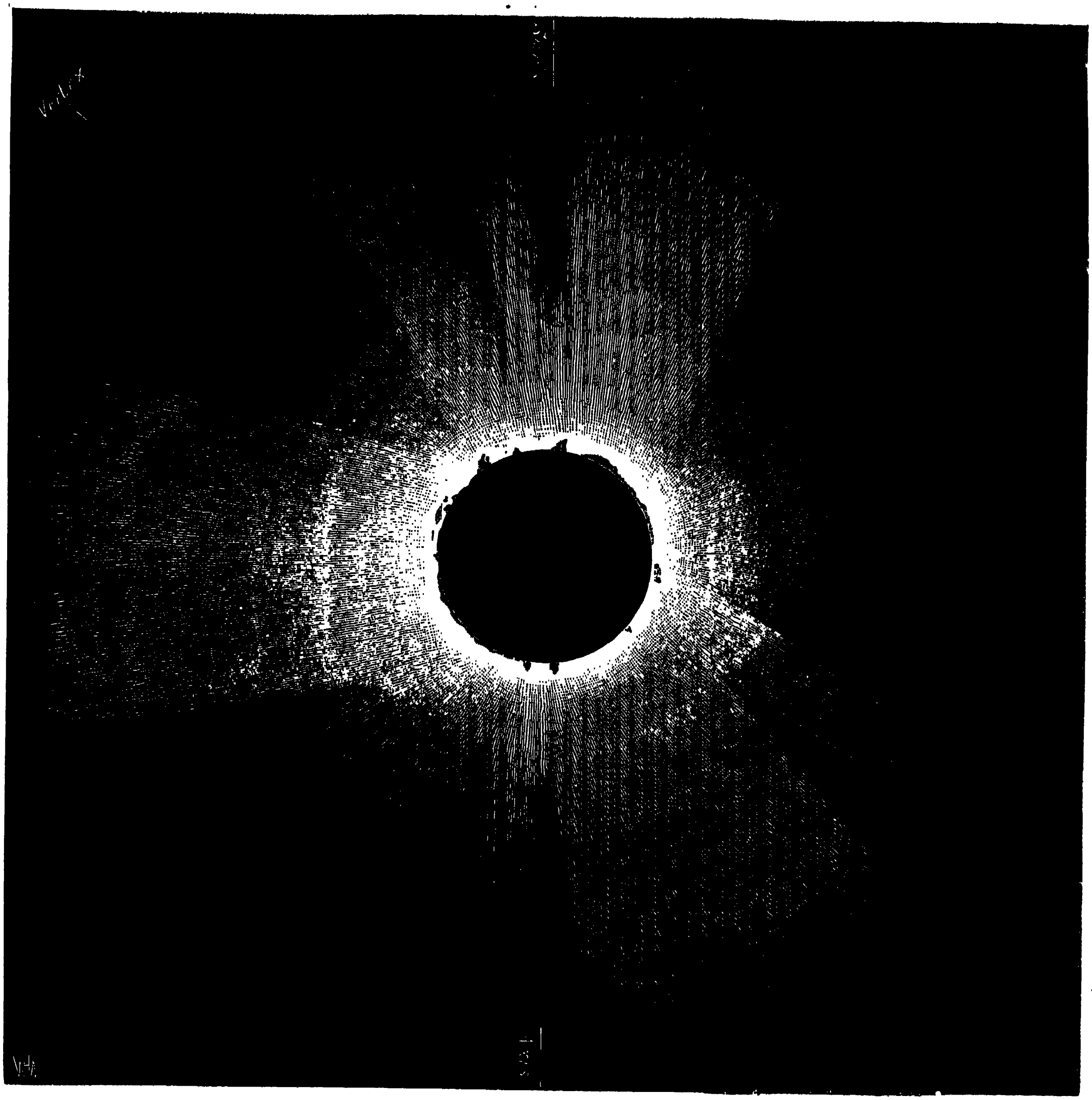
Gegen Mitte der Finsterniss sah man im Süden in einer Position von etwa 190° eine gekrümmte Ausstrahlung deren Form der Gestalt einer Leier sehr gleich kam. Ich selbst sah nur die westliche Hälfte, doch andere haben sie ganz erkannt.

(p. 15.) Die beifolgende Zeichnung, welche für mein astronomisches umkehrendes * Fernrohr gilt, wurde nach meinen während und unmittelbar nach der Finsterniss entworfenen Skizzen auf's sorgfältigste ausgeführt. Sie vereinigt die zu verschiedenen Zeitmomenten, während der Totalität gesehenen Erscheinungen in einem Bilde.

Auf der westlichen Mondhälfte stellen sich die Hervorragungen und die Corona dar, wie sie sich mir im Fernrohr, 30^s nach dem Beginn der Totalität zeigten. Die S.W. Hälfte mit Protub. und der leierförmigen Ausstrahlung gilt für eine Zeit bald nach der Mitte der Finsterniss, und die Sierra des N.W. Quadranten mit Protub. für den Moment unmittelbar vor dem Ende der Totalität.

* In making the accompanying woodcut, the drawing has been turned, to make it correspond with the others.

† Oriented from the north point, as marked by Rumker.



Secchi's drawing of the corona of 1860, July 18th.*

* Made from a steel engraving given in a pamphlet by Padre Secchi, entitled "Relazione delle Osservazione, etc.," Rome, 1860. The steel engraving has been oriented from the vertex. Assumed time of mid-totality $3^h\ 2^m\ 33^s$ local true time. Sun's axis $47°\ 46'$ to the west of the vertex.

Padre A. Secchi. 40° 5′ N. 0° 0′ Long. } DESIERTO DE LAS PALMAS, 18th July, 1860.

"Comptes Rendus," li., p. 158.

The light of the corona was more brilliant on the side where the sun had disappeared, otherwise its light was uniform all round without interruptions, to a distance of a lunar radius. Outside this distance there were rays which extended to 40′ from the moon. M. Cepeda saw branched rays like stags' horns in the upper part.

Pendant tout ce temps, la couronne était magnifique, mais plus brillante* du côté où le soleil s'était caché. Du reste, sa lumière était tout autour uniforme et sans interruption, d'un beau blanc argenté et s'évanouissant graduellement en partant du bord de lal une jusqu'à une distance d'environ un rayon lunaire au moins. À cette distance, elle commençait à avoir plusieurs interruptions, et de larges faisceaux s'en échappaient; mais ceux de la partie supérieure étaient alors plus longs, et arrivaient au moins à un diamètre et un quart de la lune. Dans la partie inférieure, je ne vis qu'un de ces longs faisceaux. . . .

(p. 160.) M. CEPEDA, qui observait avec une excellente lunette à grand champ, assure qu'il a vu un faisceau de ces rayons courbes et divisé en branches comme le bois des cerfs vers leur partie supérieure.

Don Antonio Aguilar. 40° 5′ N. 0° 0′ W. } DESIERTO DE LAS PALMAS, 18th July, 1860.

"Ueber Totale Sonnenfinsternisse":
Prof. von Mädler, p. 27.

Rays 1° long pierced the corona. To the right of the north point there was a curved ray.

Das Ende der Totalität war nahe; ich blickte durch den sucher des Fernrohrs nach der Corona. . . .

Strahlen von der Länge des doppelten Monddurchmessers durchzogen sie. 40° rechts vom Nordpunkte zeigte sich ein Strahl wie ein gekrümmter Baumast. Ich fand sie nichte in concentrische Ringe getheilt, sondern den Glanz allmählich von innen nach aussen abnehmend. Ueberhaupt war ihr Licht sehr ungleich.

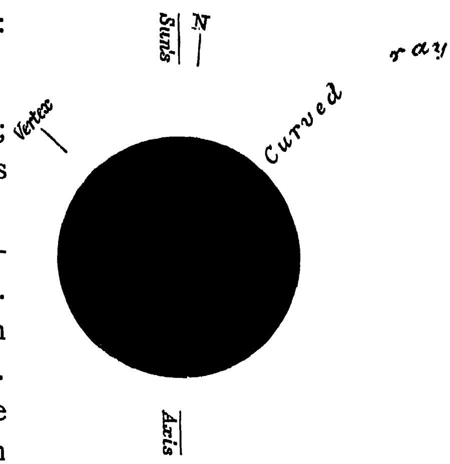


Diagram constructed to illustrate Aguilar's description of the corona of 1860, July 18th.†

* In the Italian account, "Relazione delle Osservazione, etc.," P. Secchi says, at p. 15, "Essa [the moon], era cinta tutta intorno da una brillante corona di gloria alquanto più viva ma non più larga dal lato dove il sole si era occulato."

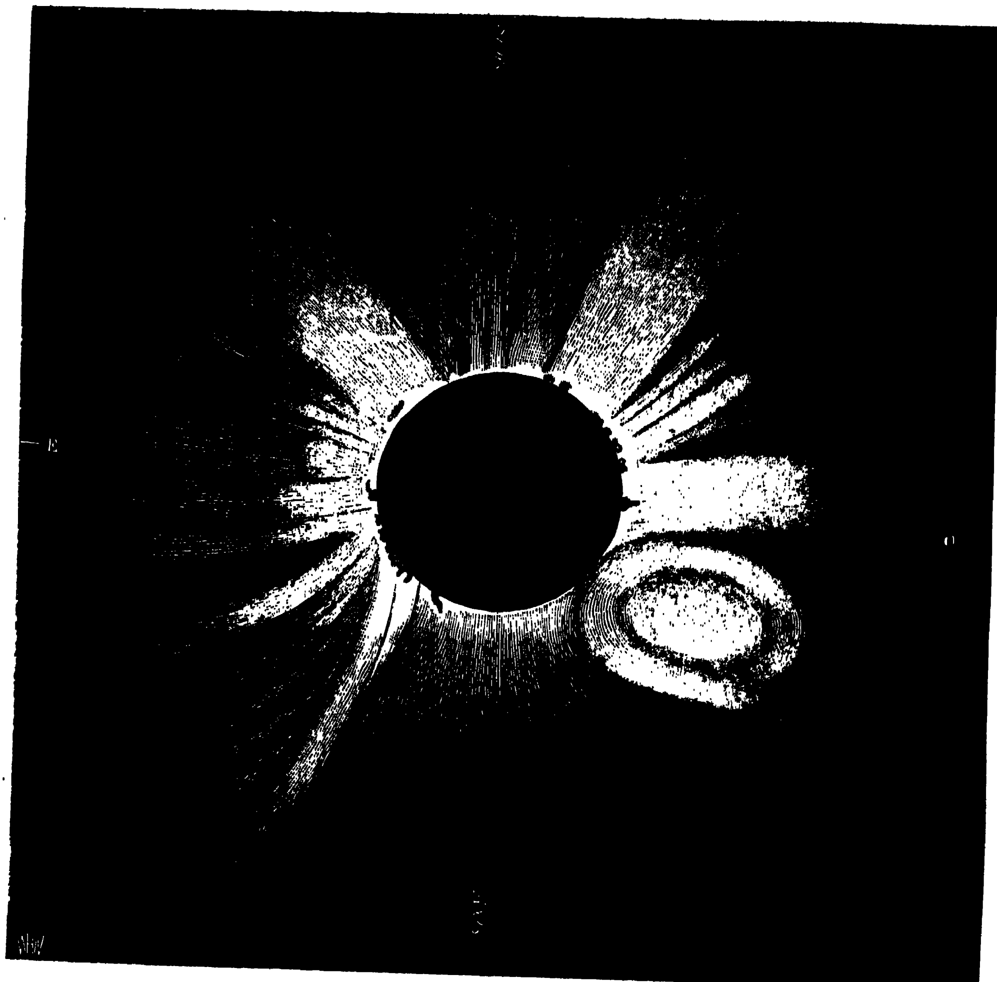
† Assumed time of mid-totality $3^h\ 2^m\ 33^s$ local true time, Sun's axis 47° 46′ to the west of the vertex.

Signor Guglielmo Tempel.

40° 15′ 10″ N. } TORREBLANCA,
0° 10′ E. } 18th July, 1860.

"Annali del R. Museo di Fisica di Firenze," Nuova Serie, Vol. i., p. 28.

Facciamoci ora a considerare la tavola disegnata ed incisa dal



Tempel's drawing of the corona of 1860, July 18th.*

signor Tempel, la quale rappresenta le apparenze notate nel tempo della

* The above woodcut has been made from a lithographic plate given in the "Annali del R. Museo Fiorentino." It has been oriented from the points of the compass marked upon the plate by Donati, with the sun's axis 5° 26′ to the east of the north point.

Description of Tempel's drawing, by Donati.

totalità dell'eclisse.* Tutte le immagini in essa disegnate sono quali apparivano direttamente nel cannocchiale che rovesciava. L' orizzonte di Torreblanca corrisponde al lato orizzontale di questa tavola sul margine della quale sono poi segnati i punti N. O. S. ed E. determinati giusta gli angoli di posizione osservati da me.† Si vedrà che in questa Tavola sono rappresentati quattro diversi aspetti dell'eclisse totale. Nel quadro più grande è rappresentata l' eclisse quando era nel suo mezzo, e vi si vedono tutte le protuberanze, la corona e i raggi stravagantissimi che da questa sembravano emanare. Degli altri tre quadretti ‡ più piccoli, il primo quadretto, in alto della Tavola, si riferisce al principio dell' eclisse totale, ed in esso si vedono le protuberanze dalla parte dell' Est, mentre non vi sono per anche visibili le protuberanze dalla parte dell' Ovest; il secondo quadretto rappresenta l' aspetto dell' eclisse un poco dopo il suo mezzo, e vi si vedono le protuberanze orientali molto diminuite di altezza, mentre se ne scorgono delle nuove apparse ad occidente che in principio non erano visibili e già divenute assai alte; il terzo quadretto, in basso della tavola, rappresenta l' aspetto dell' eclisse totale poco prima della sua fine.

M. C. Bulard. 35° 29′ N., 6° 22′ E. — LAMBESSA, 18th July, 1860.

"Comptes Rendus," liii., p. 511.

The corona chiefly composed of a dazzling white ring, from the midst of which sprang four rays forming a cross.

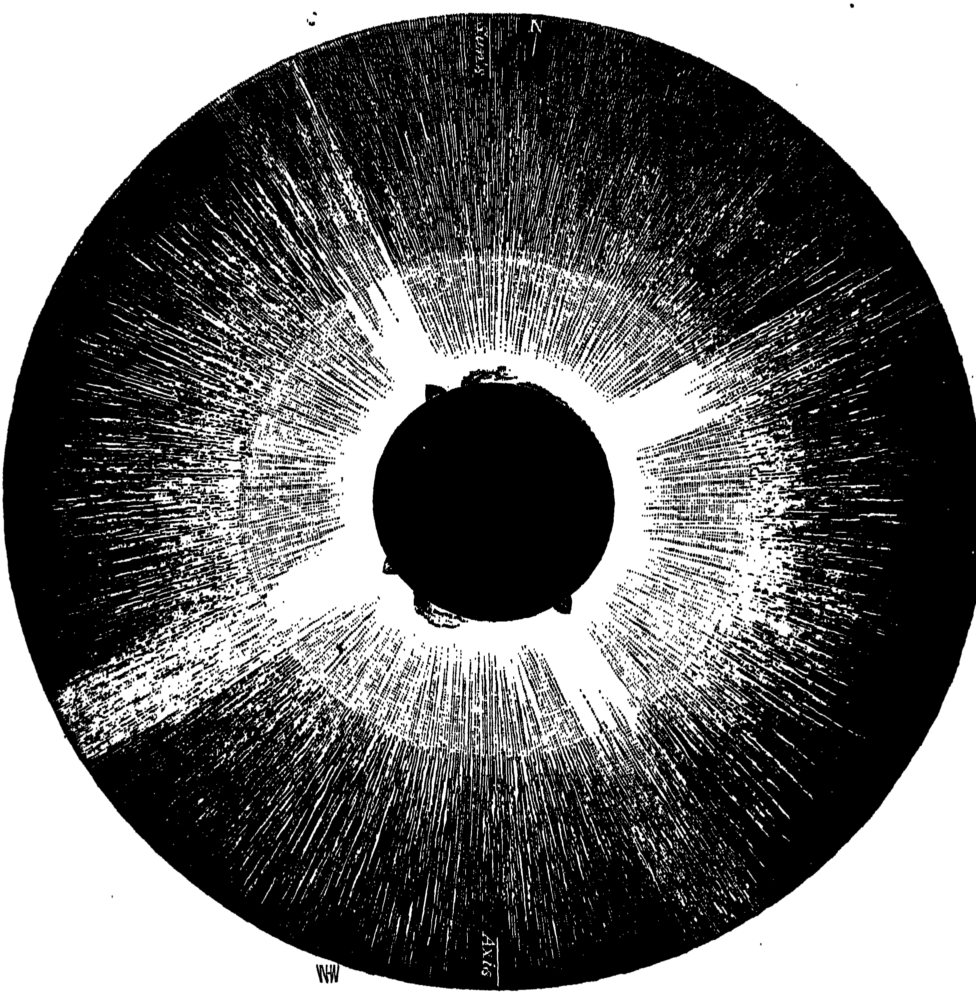
L'auréole se composait principalement d'une zone annulaire d'une blancheur éclatante, dans le sein de laquelle prenaient naissance des rayons plus ou moins brillants. On y distinguait au premier coup d'œil quatre larges faisceaux formant une croix très-marquée. Le dessin

* The description is by Sig. G. B. DONATI: only the largest of the four pictures of the corona referred to has been copied.

† There seems to be an error of some 12° in the position of these orienting lines as marked by Donati. If we take the time of mid-totality as $3^h\ 3^m\ 12^s$ *local true time*, the angle between the declination circle through the sun's centre and the vertical for Torreblanca would be 52° 56′, whereas Donati seems to have taken it as 41° 3′. See p. 27, where he says, "Avendo calcolato che per il momento della massima oscurazione l'equatore celeste faceva coll' orizzonte di Torreblanca un angolo di 41° 3′." The above woodcut was made before the error was noticed.

‡ Woodcuts have not been made from the smaller drawings, as they do not show the whole extent of the corona, and appear to have been made principally with the object of showing the appearance of the prominences as the eclipse progressed.

d'ensemble en représente fidèlement l'aspect, sauf peut-être quelque dureté dans les contours extrêmes de l'auréole intérieure.*



Bulard's drawing of the corona of 1860, July 18th.†

* After describing the prominences, M. Bulard goes on to speak of two rays, which would seem from his description to have belonged to the corona, and to have curved together in a synclinal manner. His description runs thus : " Enfin, parmi les particularités que j'ai notées et mesurées, je citerai deux rayons rectilignes divergents très déliés, d'un grand éclat et parfaitement blancs, qui semblaient émaner d'un point situé à l'intérieur d'une des grandes protubérances en forme de feuille de tulipe. . . . ."

† The above woodcut was made from a large drawing sent by M. Bulard to the Astronomer Royal. It has been oriented from the north point, as marked on the drawing by M. Bulard.

Attempts to Photograph the Corona of 1860, *July* 18*th*.

M. Warren De La Rue. 42° 43′ 24″ N. 2° 55′ 20″ W. RIVABELLOSA, 18th July, 1860.

"Bakerian Lecture," published in the *Phil. Trans.*, part 1, 1862.

(p. 30.) The Kew heliograph, with which the photographs were obtained . . . . was devised by myself, for the special object of making photographs of the sun's disk . . . . The object-glass has 3·4 inches clear aperture and 50 inches focal length; the primary focal image of the sun at his mean distance is 0·466 inch in diameter, but before it is allowed to fall on the sensitive plate, it is enlarged to about 3·8 inches by means of an ordinary Huyghenian eyepiece.* In the plane of the focus of the posterior lens of this eyepiece are attached two position-wires, which cross at right angles, and which were adjusted approximately into a position at an angle of 45° to a parallel of declination.

[Two photographs were taken during totality, each with an exposure of about 60 seconds, but only slight traces of the corona were obtained, The photoheliograph seems to have been slightly shifted during the exposure of the second photograph, and three images of the brighter prominences were obtained. With regard to the photographic intensity of these prominences Mr. De la Rue remarks:—]

(p. 73.) With the aperture of the object-glass reduced to 2 inches in diameter, and using the instantaneous apparatus, a picture of partial phase could have been procured in $\frac{1}{20}$th of a second, and therefore in less than $\frac{1}{68}$th of a second with the full aperture of the telescope. Moreover, as in the second totality-picture the prominences were depicted three times, in consequence of two disturbances of the telescope in right ascension, during the minute the plate was exposed in the heliograph, we know that on the average 20 seconds are about sufficient to bring out the picture of the luminous prominences strongly. These triplicate images are not, however, of equal intensity, one being very faint; and

* If we neglect the absorption due to the lenses of the eyepiece, and speak of the intensity of the image in the principal focus of a telescope of aperture 1, and focal length 10 as unity, the intensity of the image thrown upon the photographic plate, by the arrangement made use of, would be represented by ·007. The sky appears to have been perfectly clear at the time when the photographs were taken, and the sun was at an altitude of a little more than 49° 30′ above the horizon.

therefore, assigning to this latter (what its appearance warrants) an exposure of half the time of the other two, we have 12 seconds as the time required to depict the most luminous of the prominences fairly. It results, therefore, that the light of the luminous prominences is fully $58 \times 12 = 696$ times less bright than that of the photosphere of the sun.

Padre A. Secchi.	40° 5′ N.	DESIERTO DE LAS PALMAS,
Prof. Monserat.	0° 0′ long.	18th July, 1860.

"Comptes Rendus," li., p. 160.

Le directeur M. ANTONIO DE AGUILAR m'avait engagé à apporter la grande lunette de Cauchoix montée sur un très-solide piedé quatorial enfonte et mue par une horloge, pour faire des photographies solaires. Outre les épreuves nombreuses du soleil entier, on a fait quartorze épreuves des phases agrandies, et cinq de grandeur naturelle de l'image focale de 23 millimètres de diamètre, et qui representent toutes les phases du phénomène. . . . La force de la lumière des protubérances est telle, qu'une épreuve est venue triple—par une secousse instantanée donné à la lunette. Dans cette opération délicate, M. Monserat, professeur de chimie à l'Université de Valence, c'est chargé de toutes les opérations photographiques, et mon confrère le P. Vinader a assisté à la marche et au règlement de la lunette.

NOTE.—See also Padre Secchi's "Relazione delle Osservazioni fatti in Spagna," 8°, Rome, 1860, p. 21. Negative No. 3 was exposed for 30 seconds; in it the extension is greatest. The drawing for the lithographic plate has been made from paper copies from the negatives which were sent to the Astronomer Royal by Don Antonio Aguilar soon after the eclipse; these photographs have now somewhat faded. From a letter written by Padre Secchi to the Astronomer Royal, it appears that the first photograph was exposed for 6 seconds immediately after the disappearance of the sun; the second photograph was lost by a movement of the instrument which left three images on the plate; the third photograph was exposed for about 60 seconds; the fourth photograph was exposed from 10 to 15 seconds; the fifth photograph was also exposed from 10 to 15 seconds; the sixth photograph was destroyed by the re-appearing sun.

In a letter dated October, 1879, Prof. TACCHINI informs me that the original negatives cannot be found at the Observatorio Romano. The aperture of the Cauchoix telescope is $0{\cdot}15^{m}$ and its focal length $2{\cdot}50^{m}$. The intensity of the image in its principal focus would consequently be ·0036.

Eclipse of 1867, August 29th.

Wolf gives 9·2 as the monthly relative number for August, 1867, showing that the solar activity, as indicated by sun spots, was at a very low ebb at the time of the eclipse. If we rely on the evidence of Grosch, which seems to be supported by that of Vidal, the corona visible during this eclipse was very extensive, especially in the equatorial regions. As shown in the sketch, it extends to a distance of more than 40′ from the sun's limb. Grosch describes the equatorial rays as *diverging* in symmetrical bundles, and there is nothing either in the description or in the drawing that would indicate the existence of groups of synclinal structure. The corona appears to have borne a close resemblance to that observed during the sun-spot minimum eclipse of 1878.

Herr L. Grosch. Colchagua, near Santiago,
Lieut. Vidal. 29th August, 1867.

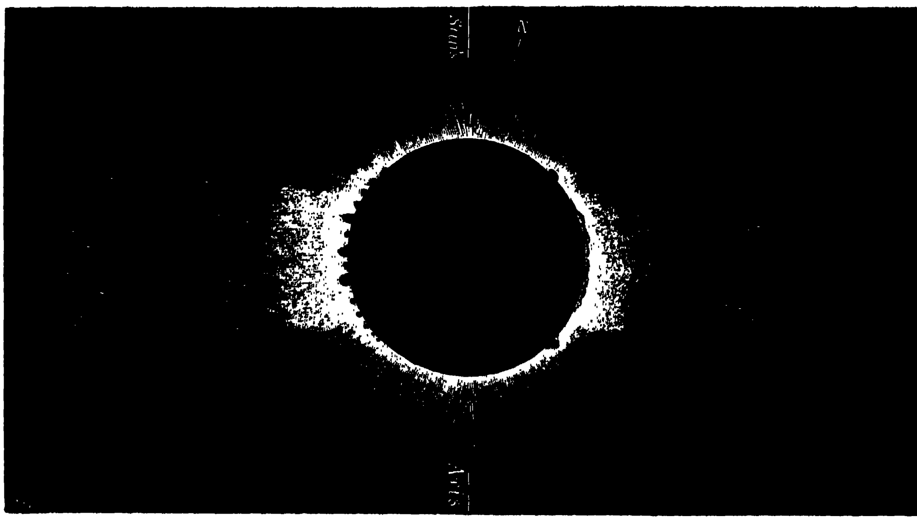
"Astr. Nachr.," Vol. lxxiii. pp. 139, 140.

The picture represents the corona as seen with the naked eye. The light of the corona extended further in the neighbourhood of the sun's equator than in the neighbourhood of the sun's poles. At the north pole dark rays were seen curving symmetrically in either direction. They appeared darker than the background, as if drawn with lead pencil upon white paper. Lieut. Vidal saw similar rays at the south pole.

Was nun die Corona betrifft, so war dieselbe in der Richtung des Aequators der Sonne bedeutend länger ausgedehnt und ihrem Wesen nach muss dieselbe, wie ich glaube, entschieden getrennt betrachtet werden. Während dieselbe in der Richtung der Pole den Mond um ein Drittel seines Durchmessers überragte, erreichte sie rechtwinklig auf jener Richtung eine Ausdehnung von $\frac{4}{5}$ des Durchmessers desselben. Das Licht derselben war ein weisses am Mondesrande helleres, nach Aussen allmählig schwächer werdendes.

Dieses weisse Licht war durchaus nicht strahlig, doch schien es von Strahlen durchdrungen, oder wie es den Eindruck machte, als liefen über demselben Strahlen hinweg, besonders in der Richtung nach Ost und West, symmetrische nach Aussen divergirende Bündel bildend und die Greuzen des weissen Lichtes weit überschreitend. Diese Strahlen hatten ein mehr bläuliches Ansehen und können am besten mit denen eines grossen electro-magnetischen Kohlenlichtes verglichen werden. Sie hatten mit diesen eine solche frappante Aehnlichkeit, dass ich dieselben unter anderen Umständen für solche aus grosser

Ferne leuchtende gehalten haben würde. Dieses hier beschriebene Bild der Corona ist das mit freiem Auge gesehene; ich verwendete hierauf nur wenig Zeit, eben nur so viel als nöthig war, um flüchtig ein ohngefähres Bild der Totalansicht zu gewinnen. Ausserdem wollte ich eine andere Erscheinung, die mir zu wichtig erschien, nicht aus dem Auge verlieren; diese zeigte sich genau am Nordpunkte der Sonne. In dem weissen Lichte der Corona, dicht über dem Mondrande,



Grosch's drawing ot the corona of 1867, August 29th.*

erschienen mehrere dunkle curven; dieselben waren symmetrisch nach Osten und Westen umgebogen, scharf gezeichnet, im Farbenton gleich den mit einer Bleifeder auf weissem Papier gezogenen Linien und machten den Eindruck, als gingen sie von einem Punkte aus, der sich

* The above woodcut was made from a lithographic plate given in the "Astr. Nachr." In the text, the equatorial rays are described as extending to $\frac{4}{6}$ths of a diameter, but they are given in the lithographic plate as extending to a distance considerably greater than a lunar diameter. The drawing embodies the rays in the neighbourhood of the sun's southern pole observed by Vidal. It has been oriented by Grosch with the sun's axis horizontal upon the page. The position of the sun's axis relatively to the corona, as given by Grosch, has been adopted for the woodcut, although it is evident that there is a mistake either in the position of the sun's axis or of the north point as laid down by Grosch upon the lithographic plate, for at the date of the eclipse the sun's axis was 20° 34′ to the left of the north point. As shown upon the plate and in the woodcut, the sun's axis is about 12° to the left of the north point.

Grosch's observation.

jenseits des Mondes befinde, aber vom Rande desselben aus etwa 2° näher dem Centrum der Sonne liegen müsse. Sie hatten ihren Anfang in 1′ und verloren sich in circa 9′ Entfernung vom Mondesrande. Während der Dauer der Finsterniss erlitten sie durchaus keine Veränderung; sie blieben constant in Form und Farbenton bis zum Verschwinden der Corona. Lieutenant Vidal, dem sich Sr. Vergara anschliesst, giebt das Stattgefundenhaben einer ähnlichen Erscheinung, in Form eines fächer—oder garbenförmigen Lichtbüschels genau am Südpunkte an; erwähnt jedoch Nichts von den charakteristischen dunklen Curven, wie ich solche am Nordpunkte gesehen habe.

Es steht übrigens der Annahme der Richtigkeit der Angabe durchaus Nichts entgegen, da diese dunklen Curven auf eine starke magnetisch polare Kraft der Sonne hindeuten und also eine derartige Erscheinung so gut wie am Nordpunkte auch am Südpunkte statthaben konnte; es war dieselbe vielleicht dort weniger entwickelt und desshalb nicht so leicht wahrnehmbar.

Eclipse of 1868, Aug. 18th.

The photographs taken at Aden and Guntoor during this eclipse, though excellent as pictures of the prominences, were not sufficiently exposed to show more than traces of the lowest parts of the corona. SUTTON endeavoured to photograph the corona as seen with a clear sky at a high altitude above the horizon: the attempt was made in the principal focus of an achromatic telescope the focal length of which was nearly nineteen times the diameter of the object-glass, but not the slightest trace of the corona seems to have been obtained. We must, therefore, rely on the drawings and descriptions of observers for information with regard to the corona visible during this eclipse. Attempts to photograph the corona.

BULLOCK's and FAURO's drawings show great groups of rays making angles greater than 45° with the sun's axis. SUTTON's drawing, made from the image of the corona as seen projected upon the ground glass of a camera, confirms BULLOCK's and FAURO's as to the three chief groups of rays in the north-western, north-eastern and south-eastern sections of the corona; these three groups are also given in the drawings made by the observers at Wha-Tonne. All the above drawings also agree as to the existence of a smaller group of structure in the south-western region of the corona, though they differ as to the form of the smaller group. Comparison of drawings.

Two of the Wha-Tonne drawings represent the south-western group as divided into three lesser groups. This agrees with the description given by TIELE, who observed at Aden. He speaks of a group of structure 40° to the right of the lowest point (which in the oriented corona would correspond with the position of the south-western group), and describes it as consisting of three tufts of rays ("Strahlenbüschel") nearly perpendicular to the moon's limb. The central tuft was smaller than the two outer ones. The rays of which these tufts or groups of rays were composed were not straight, but "turned their somewhat concave sides together." The synclinal character of these three lesser groups is also indicated in the drawing of OLRY. STEPHAN, too, refers to the curving nature of the structure in this part of the corona, and describes it as reminding him of a curving skein of thread ("écheveau recourbé"). Synclinal character of group of rays in S.W. quadrant.

Synclinal rays in S.E. section of the corona.

WEISS describes the group of structure in the south-eastern section ot the corona as consisting of two groups of rays separated by a darker space and curving with their concave sides turned towards one another, so that the whole reminded him of a parabolic arc with its vertex towards the moon,—a description which resembles GOLDSCHMIDT's description of the synclinal group of structure in the south-western section of the corona of 1860.

Pope Hennessy's drawing.

POPE HENNESSY speaks of structures in the corona which reminded him of "horses' tails," and of "bands" falling towards one side with other bands falling towards the other side—as if referring to rifts in the corona, bounded by rays curving away on either side. There seems to be some doubt as to the proper orientation of his drawing, but according to the orientation which has been adopted, the rifts formed by the rays curving away from one another are situated at opposite ends of a solar diameter which was inclined about 30° to the sun's axis. As seen from Barram Point, the sun's axis was about horizontal, and consequently the long rays extending "in bands to a distance more than twice the diameter of the sun," which POPE HENNESSY describes as "from the upper and lower parts," must have corresponded to rays in the equatorial regions, and were probably the long rays or groups of structure drawn by BULLOCK and others. The observers at Masulipatam all give quadrilateral drawings of the corona; WINTER and POGSON agree with OLRY, BORDES and the other observer at Wha-Tonne, and BULLOCK at Mantawalu Kiki, in giving the longest groups of structure in the north-western and south-eastern sections of the corona, and also in representing the axes of these groups as making angles greater than 45° with the sun's axis.

Groups of structure make angles greater than 45° with sun's axis.

Taking all the observations together, it would seem that there were four principal groups of structure, whose axes made angles greater than 45° with the sun's axis. There is evidence tending to show that at least two of these groups were composed of synclinal structure; and there can be little doubt that the development of the corona in the equatorial regions was decidedly greater than in the neighbourhood of the sun's poles.

Sun spots.

WOLF gives 42·9 as the monthly relative number of sun spots for August 1868, and it would seem that the corona was intermediate in type between the sun-spot maximum corona of 1871 and the sun-spot minimum corona of 1878.

Dr. B. Tiele. 12° 45′ 47″ N. } 45° 2′ 55″ E. } ADEN, 18th August, 1868.

Sitzb. d. Vienna Akad. d. Wissensch., II. Abth., Dec. Heft, 1870.

(p. 29.) In der Pause zwischen dem zweiten und dritten Bilde hatte ich Zeit einen flüchtigen Blick mit blossem Auge auf die Erscheinungen zu werfen, und habe mir darüber gleich nach der Totalität folgendes notirt.

Der dunkle Mond war rings von einem hellen Scheine umgeben, der sich vom Mondrande aus allmälig abschwächte, und während er in unmittelbarer Nähe des Gestirnes mehr den Eindruck einer continuirlichen Lichtmasse machte, nach Aussen zu ein strahliges Aussehen annahm. Die Breite und Helligkeit war verschieden $1\frac{1}{2}'$—$3'$ im Mittel $2'$. Die hellste Stelle zeigte sich gerade nach dem Zenith, und hier war auch die Breite des scheinbar continuirlichen Lichtes am grössten. Vom unteren Rande, etwa 40° nach rechts * (natürlich direct gesehen), war zunächst ein breiterer, strahlenförmiger Saum von etwa 30° Ausdehnung, und von diesem aus gingen drei längere Strahlenbüschel, ungefähr senkrecht auf den Mondrand, aus, der mittlere kleiner als die beiden äusseren; diese waren nicht geradlinig, sondern kehrten ihre etwas concaven Seiten einander zu. Sie konnten $\frac{3}{4}°$ bis höchstens 1° weit verfolgt werden, worauf sie sich in den rings umgebenden Wolken verloren. Ich glaube, dass auch an einer nahe 180° von hier entfernten Stelle des Mondrandes radiale Strahlen ausliefen, doch weit schwächer als die eben beschriebenen.

In the pause between the second and third pictures, I had time to take a hurried glance with the naked eye. The dark moon was surrounded to a distance of from $1\frac{1}{2}'$ to $3'$ by a ring of continuous light. About 40° to the right of the lowest point of the moon's disc were three bundles of rays at right angles to the moon's limb the smallest in the middle. These were not rectilinear rays, but their sides were somewhat curved with the concavities turned together. They were at most 1° long, beyond which distance they were lost in the surrounding clouds. Tiele thought that he saw a similar but fainter group on the opposite side of the moon.

Dr. Edmund Weiss. 12° 45′ 47″ N. } 45° 2′ 55″ E. } ADEN, 18th Aug., 1868.

Sitzb. d. Vienna Akad. d. Wissensch., II. Abth., Dec. Heft, 1868.

(p. 10.) Für die Untersuchung der Corona war die zweite Minute der Totalität am geeignetsten. In derselben bildete sie durch das Fernrohr gesehen, den Hauptsache nach, einen matten Ring von silberweisser Farbe um den Mond, der vom Mondrande weg gleichmässig an Intensität abnahm, und sich in einer Entfernung von 6′ bis 8′ allmählig im Hintergrunde verlor. Sehr nahe bei jener Stelle, wo der letzte Sonnenstrahl verschwunden war, ragten zwei helle, durch einen etwas dunkleren Zwischenraum getrennte Strahlenbüschel aus ihr hervor, die sich an ihrer Wurzel mässig krümmten, und die concaven Seiten der Krümmung

Near to the place where the last ray of the sun disappeared were two bright rays, which curved rather together at their base, and had a dark space between them: the whole had the appearance of the arc of a parabola with its vertex at the moon's limb.

* As seen from Aden, the north point of the sun's axis was about 86° to the left of the vertex.

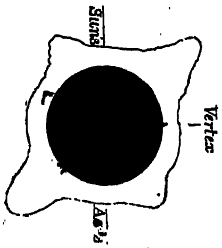
einander zuwendeten, so dass das Ganze einem mit seinem Scheitel am Mondrande aufsitzenden parabolischen Bogen nicht unähnlich sah. Die beiden Strahlenbüschel reichten bei centrirter Mondscheibe über das Gesichtsfeld des Oculares hinaus, waren also länger als 20′.

A second group of rays was observed towards the end of totality, in the S.W. quadrant. It occupied about 40° of the moon's circumference, and extended to a distance of 12′ or 15′ from the limb. Clouds covered the northern part of the moon during the observation.

Gegen das Ende der zweiten Minute der Totalität bemerkte ich im südwestlichen Quadranten noch ein zweites Strahlenbüschel, das mir früher nicht aufgefallen war. Es hatte an seiner Basis etwa 40° Breite, war an beiden Seiten durch gerade, scheinbar senkrecht auf dem Mondrande stehende Linien begrenzt, und stand etwas südlich von jener Stelle, an welcher die Totalität ihr Ende fand, mochte also in seiner Mitte einen Positionswinkel von etwa 230° besitzen.* An Länge kam dieses Strahlenbüschel dem früher erwähnten nicht gleich, sondern verlor sich schon in einer Entfernung von 12′ bis 15′ im Hintergrunde. Ob in nordöstlichen und nordwestlichen Quadranten ähnliche Bildungen in der Corona vorkamen, kann ich nicht angeben, da die Wolken hier dem Mondrande stets zu nahe standen.

Mr. N. R. Pogson. 16° 11′ 33″ N., 81° 12′ 15″ E. MASULIPATAM, 18th Aug., 1868.

Report of the Government Astronomer.



Outline of the corona as drawn by Pogson, 1868, Aug. 18th.†

(p. 6.) Of the corona I regret to be able to give little or no account, my time and attention having been so completely taken up with the micrometrical and spectroscopical measurements of the prominences. I cannot even say whether it came immediately or gradually into view in the telescope, but its light was of a pure white silvery nebulous nature for two

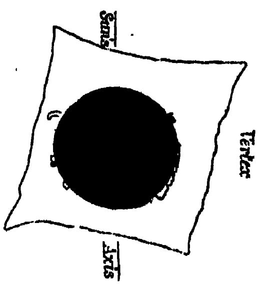
* The angles are measured from the north point: the north pole of the sun's axis was 17° 23′ to the east of the north point. Consequently the above-mentioned ray would be in the south-western region of the corona, about 33° from the sun's southern pole. Dr. Weiss gives a diagram at the end of his paper showing the above-mentioned rays in the south-eastern and south-western quadrants. On comparing the position of these rays with that of the great prominence, it will be seen that the parabolic arc corresponds in position with the great group of structure shown in the south-east section of the corona in BULLOCK's and SUTTON's drawings; while the broader and shorter ray in the south-west region corresponds fairly in position with the smaller ray or group of nearly radial structure shown in the south-west quadrant in BULLOCK's drawing. A smaller drawing by Col. ADDISON is also given in Weiss's report, showing some rays in the polar regions. Both of the drawings were made through gaps in cloud, and cannot be taken as representing the whole of the corona.

† A coloured lithographic plate is given with two drawings of the corona as observed by

or three minutes of arc from the moon's limb, when its homogeneous appearance ceased, and it seemed to radiate from the sun's centre until lost in the surrounding hazy sky. To the naked eye, however, a hasty glance, while passing from one telescope to the other, exhibited two long and broad radial arms of unequal length, and two others, considerably shorter, nearly but not quite perpendicular to the former pair; but in what direction these singular radial arms lay, I had no time to note, and recollection would not serve me safely to assert.

Mr. C. G. Walker. 16° 11′ 33″ N., 81° 12′ 15″ E. MASULIPATAM, 18th Aug., 1868.

Report of the Government Astronomer.



Outline of the corona as drawn by Walker, 1868, Aug. 18th.*

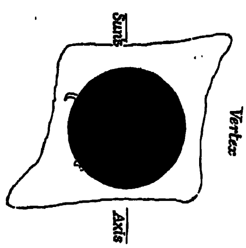
(p. 18.) The corona was of a singularly pure white light, less brilliant at its outer edges. It seemed radiant, shot out from the sun's disc; the radial character being most strongly marked as the edges were approached. I saw no apparent movement. Taking the apparent position of the disc, as before [that is, measuring from his estimated position of the north point through the east], there was a strongly projecting branch of the corona at about 35° from the centre of the upper limb on the left, and exactly opposite (*i. e.* on the lower right hand side) a less prominent arm or branch. At about 60° from the centre of the lower limb there was another projection, rounded, not pointed, and a similar one exactly opposed to it. The respective angles of position I estimate at about 315° for the larger branch, 135° for the smaller one, and 40° and 220° respectively for the other two. But I speak with diffidence about the corona. As I said, I regretted the high power I had on my telescope, and it was because I could not command, as it seemed to me, the whole corona at once. This destroyed my clear idea of its shape, although its colour and *texture* were well seen.

Mr. Pogson, "immediately after the sun's disappearance," and "immediately before the sun's reappearance." The outline of the corona differs but slightly in the two drawings. The above woodcut has been oriented by means of the great prominence.

* Made from a coloured lithographic plate, and oriented from the position of the great prominence, the position angle of which is given by DE LA RUE, from the measurement of TENNANT's photographs, as 80°.

Mr. G. K. Winter. 16° 11′ 33″ N. } 81° 12′ 15″ E. } MASULIPATAM, 18th Aug., 1868.

Report of the Government Astronomer.



Outline of the corona as drawn by Winter, 1868, Aug. 18th.*

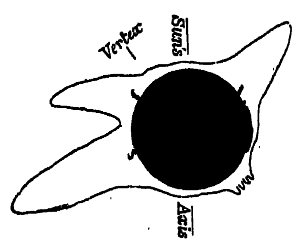
(p. 20.) The corona seemed to burst into being at the first moment of totality. Its colour was silvery white. It was slightly mottled near the sun, and nearer to its edges was beautifully striated, radially from the sun, at four points—namely, about N.E., N.W., S.E., and S.W. It extended to a greater distance from the sun than at other parts, the branches from the N.W. and S.E. being much the longest and most conspicuous.

The accompanying drawing will give some idea of the shape and appearance of this phenomenon.

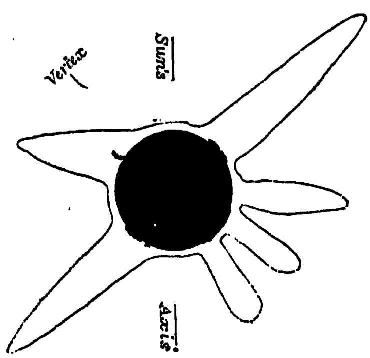
M. E. Stephan. 11° 42′ 35″ N. } 99° 47′ 45″ E. } WHA-TONNE, 18th Aug., 1868.

Rapport sur l'observation de l'éclipse, par M. Stephan.

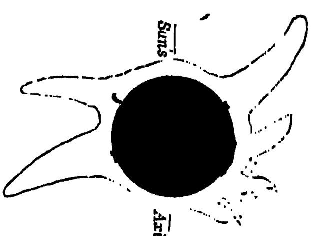
Being occupied with the prominences, M. Stephan was not able to examine the whole of the corona. The structure in the S.W. section resembled a curved skein or tangle of threads. According to the drawings of MM. Olry and Bordes, the corona was crossed by four groups or far-reaching jets, corresponding with the prominences.



Bordes' drawing of the corona of 1868, Aug. 18th.



Olry's drawing of the corona of 1868, Aug. 18th.†



Drawing given in M. Stephan's Report.

(p. 28.) Absorbé par la mesure des protubérances, il m'a été impos-

* Made from a coloured lithographic plate, and oriented from the position of the great prominence.

† The above outline woodcuts are made from coloured lithographic pictures of the corona, given in M. Stephan's report. M. Olry is described as "lieutenant de vaisseau, chef d'état-major de l'amiral Ohier;" M. Bordes as "lieutenant de vaisseau." The third woodcut is made from three drawings, all very similar to one another. The name of the artist does not appear to be given. All the woodcuts have been oriented by means of the great prominence.

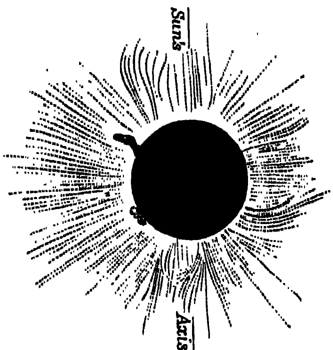
sible d'examiner la couronne dans toute son étendue; je ne l'ai observée que dans la portion située au-dessus du groupe *d* [that is, in the south-west section of the corona, about position angle 230°], elle y affectait très-nettement la forme en écheveau recourbé dont parle ARAGO. Sa couleur était tout à fait blanche. Des dessins de MM. OLRY et BORDES, il résulte que la couronne était traversée par quatre groupes de jets très-étendus ou gloires correspondant sensiblement aux protubérances. . . . .

(p 30.) Quelques-uns des officiers cherchèrent à mesurer le diamètre de la couronne, mais sans succès. Nous devons nous en tenir à l'appréciation du dessinateur.

Governor Pope Hennessy. 4° 35′ N., 113° 55′ E. BARRAM POINT, BORNEO, 18th August, 1868.

"Proceedings of the Royal Society," Recess 1868, p. 85.

Suddenly there burst forth a luminous ring around the moon. This ring was composed of a multitude of rays, quite irregular in length and in direction; from the upper and lower parts* they extended in bands to a distance more than twice the diameter of the sun. Other bands appeared to fall towards one side; but in this there was no regularity, for bands near them fell away apparently towards the other side. When I called attention to this, Lieut. RAY said, "Yes, I see them; they are like horses' tails"; and they certainly resembled masses of luminous hair in complete disorder.



Pope Hennessy's drawing of the corona of 1868, Aug. 18th.†

I have said these bands appeared to fall to one side; but I do not mean that they actually fell or moved in any way during the observation. If the atmosphere had not been perfectly clear, it is possible that the

* Assuming the time of mid-totality at Barram Point to be $18^h\ 0^m$ Paris M. T., the north pole of the sun's axis would be 93° 2′ from the vertex to the right, and the upper and lower parts of the corona would consequently correspond to the equatorial regions.

† The above woodcut has been copied from the woodcut given in the "Proceedings of the Royal Society." It has been oriented from the position of the great prominence. It is evident that the drawing has been turned round, and that the highest part of the woodcut upon the page in the "Proceedings of the Royal Society" could not have corresponded with the highest part of the corona above the horizon.

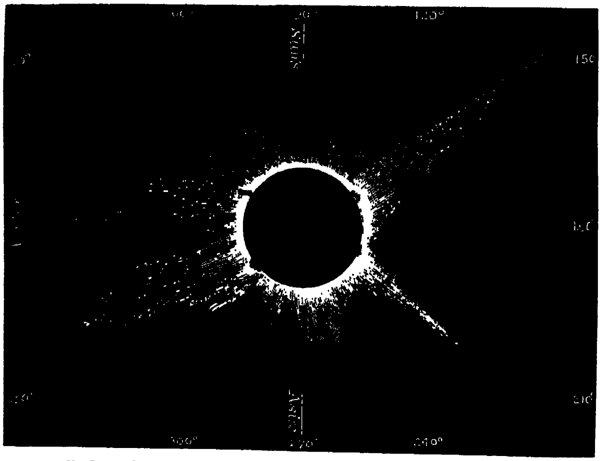
appearance they presented would lead to the supposition that they moved; but no optical delusion of the kind was possible under the circumstances.

(p. 86.) As I have not time to attempt an elaborate drawing, I content myself with enclosing to your lordship two pages from my rough notebook, showing the sketches taken at the moment.

Capt. Chas. Bullock.	0° 32′ 36″ S. 123° 4′ 48″ E.	MANTAWALU KIKI, ISLAND OF CELEBES, 18th Aug., 1868.

MS. Observations of the 1868 Eclipse.

The figure is a drawing made from an original sketch taken on the ground at the time. In describing the corona the image will be spoken of as viewed direct, and [the angles are measured] from the vertical [towards the north].


Bullock's drawing of the corona of 1868, Aug. 18th.*

The two great upper projecting masses of rays (at 330° and 360°) were bent to the left, especially towards their extremities. In the lower great projection (at 150°), the rays were perfectly straight, radiating from the centre, and terminating, according to memory, in a sharp point. The sketch differs from this, in that it presents the appearance of crossed rays at this extremity. I noticed that certainly all the shorter rays from 60° to 120° were very straight, emanating directly from the centre, and striated; but right and left of these the sketch also exhibits a confusion of crossed rays. From 160° to 300°, except as to length, the rays were very regular.

The whole outline of the corona was sharply defined; there was no indistinctness at any part of it. The drawing of the corona is made from a pencil sketch I took during the totality. It was the only one made by the English officers. Three drawings were made by Prof. OUDEMANS and

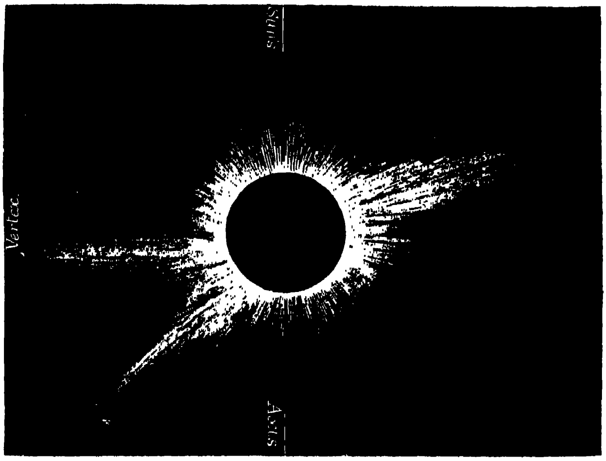
* Made from a water-colour drawing in the possession of the Royal Astronomical Society. Oriented from the position of the great prominence.

the Dutch officers, which I had not the advantage of seeing so as to compare with mine. It is to be regretted that the lengths of the rays were not ascertained: they were so distinctly defined to their very extremities that they might easily have been measured with a sextant. I believe they are not much exaggerated. As a kind of verification, it may be mentioned that, having first drawn the disc of 1½ inch diameter on the leaf of my notebook, which is 7 inches by 4½, I found the corona could not be sketched on the page, so had to turn over the leaf and reduce it to its present dimensions.

Mr. F. W. Sutton. 0° 32′ 36″ S. } 123° 4′ 48″ E. } MANTAWALU KIKI, 18th August, 1868.

MS. Observations of the 1868 Eclipse.

[Capt. BULLOCK writes:] Mr. Sutton saw the figure of the corona projected on the ground glass of the camera, and made the drawing, from which [the woodcut has been made] the same evening from memory.



Sutton's drawing of the corona of 1868, Aug. 18th.

Padre F. Fauro. 0° 32′ 36″ S. } 123° 4′ 48″ E. } MANTAWALU KIKI, 18th August, 1868.

"Beobachtungen der Totalen Sonnenfinsterniss," 8°, Halle, 1869.

(p. 6.) Kaum war der letzte Strahl des Sonnenlichtes verschwunden, als sich wie durch Zauber die schöne Corona oder Aureola ganz um die schwarze Mondscheibe zeigte.

The colour of the corona resembled that of mother of pearl or quicksilver. The three great divisions of the corona appeared to be made up of a very great number of very irregular rays of various degrees of brightness. According to P. Nonell's measurement, the rays were more than 40′ long.

Den Anblick, den sie gewährte, sieht man Fig. 1 * und 2; die Farbe

* Fig. 1 appears to be identical with the drawing by Sutton given above; and Fig. 2 differs but slightly from the drawing by Capt. BULLOCK given above. In the lithographic plate in Padre FAURO's tract (Fig. 2) there is a tangential ray about 30′ long, springing from near the place of the southernmost prominence on the western limb.

Fauro's report. aber, mit der sie sich zeichte, kann auch von einem guten Maler nicht dargestellt werden. Alle Beobachtenden stimmten darin überein, dass ihre Farbe der der Perlmutter oder des angelaufenen Silbers glich, aber von einer viel intensivern und schöner ausshenden Helle war.

Die Corona hatte drei Haupttheile, wie man an Fig. 2 sieht: der erste bestand aus einem weissen intensiven regelmässigen Licht: das von dem Rande der Mondscheibe ausströmte. Der zweite basirte auf dem ersten, indem er stufenweise an Intensität abnahm; seine Form aber war hinreichend regelmässig, wenngleich weniger intensiv. Der dritte endlich bestand in einer ausserordentlich grossen Anzahl von Strahlen, die mehr oder weniger intensiv, aber sehr unregelmässig waren, deren einige so verlängert waren, dass sie um mehr als das Doppelte den Monddurchmesser übertrafen.

Es wurde als aussergewöhnliche Erscheinung bemerkt, dass diese Strahlen von einem Augenblick zum andern ein wenig den Aublick änderten. Aufmerksamkeit verdient die etwas hellere Linie, die man das untere Bündel schräg durchschneiden sieht; diese Linie stellt einen Lichtstrahl vor, der fünf Minuten nach Beginn der totalen Finsterniss erschien und die übrige Zeit hindurch bis zu Ende blieb. Ich weiss nicht, ob bei den frühern Sonnenfinsternissen eine ähnliche Erscheinung ist bemerkt worden. Dieses erklärt die Verschiedenkeit welche man zwischen den beiden Figuren der Corona erblickt; denn, wie ich früher gesagt habe, die erste, Nr. 1, wurde abgezeichnet im Anfange von einem Bilde, das man auf dem mit Schmirgel eingeriebenen Glase der Camera obscura sah, und die andere, Nr. 2, wurde nach und nach gezeichnet und zwar indem man all die Phasen, welche sich vom Anfang bis zum Ende zeigten, zeichnete. Der P. Nonell, der seine Beobachtungen mit einem ausgezeichneten Rochonschen Fernrohre, das mit Mikrometer versehen war, machte, versuchte die Winkelgrösse eines der grössern Strahlen der Corona zu bestimmen, konnte aber nicht die vollständige Scheidung der Bilder erreichen, weil das Instrument nicht mehr als 40′ im Bogen mass.

Oblique ray seen five minutes after the beginning of totality.

Dr. G. Fritsch. **Dr. H. Vogel.** **Dr. W. Zenker.**	12° 45′ 47″ N. 45° 2′ 55″ E.	ADEN, 18th Aug., 1868.

"Vierteljahrsschrift," iii., p. 186, and also "Sitzb. d. Vienna Akad. d. Wissensch.," ii. Abth., Dec. Heft 70, pp. 27—30.

[Photographs were taken in the principal focus of a six-inch refractor of seven feet focal length. Owing to the cloudy state of the weather, the low altitude of the sun, and the comparatively short times of the exposures, the photographs show nothing but the prominences.]

Col. Tennant. **Sergeant Phillips.**	16° 17′ 29·23″ N. 80° 24′ 40″ E.	GUNTOOR, 18th Aug., 1868.

"Memoirs of the R. A. S.," Vol. xxxvii., pt. 1.

(p. 28.) The instrument employed for photography was a silver-on-glass reflector of nine inches clear aperture; the speculum by Mr. With, of Hereford, and the mounting by Mr. Browning. It was determined to adopt the Newtonian form, and to place the sensitive plates at the side of the tube, in order to find room, which would be very difficult at the mouth of the tube; the small mirror thus rendered necessary was made unusually large, in order that it might reflect all the rays from a surface of some diameter; and it was hoped that by this means, and by giving a sufficient exposure, a picture of the corona might be secured. The light clouds * so decreased the actinic power of the light as to defeat this, but still we have traces of the corona. . . . . .

(p. 29.) The small (flat) speculum had a minor axis of 3 inches across, and the tube to carry the eyepieces was 3½ inches in diameter. On to this screwed the frame, into which the dark slides slipped. This frame carried two wires at right angles to each other, which were intended to be used as the wires in Mr. DE LA RUE's arrangement in 1860, but those were in the common focus of the object-glass and enlarging lens, and were magnified with the focal image. Here no enlargement was intended, and they were placed as near as possible to the surface of the sensitive plate.

* At p. 7 Col. Tennant says: "By 8 a.m. a wedge-shaped mass of light cumulo-stratus had formed to my east, having its vertex above the sun, and extending later to the horizon. It covered the sun till nearly ten minutes after totality, and was very low." Taking the time of mid-totality at Guntoor as $21^h\ 25^m\ 16^s$ local true time, the sun must have been 52° 16′ above the horizon.

[The exposures were: Photograph No. 1, probably less than a second; Photograph No. 2, five seconds; Photograph No. 3, ten seconds; Photograph No. 4, five seconds; Photograph No. 5, one second; and Photograph No. 6, one second. The prominences are very sharply defined, but hardly any trace of the corona is to be seen on any of the photographs.]

Mr. Fredk. Wm. Sutton. 0° 32′ 36″ S. 123° 4′ 48″ E. MANTAWALU KIKI, 18th Aug., 1868.

MS. Observations of the 1868 Eclipse.

The photographs were taken direct, with one of Secretan's telescopes, the tube of which was equatorially mounted, and made to follow the motion of the sun by clockwork. The object-glass being 3½ inches in diameter and 66 inches focal length, the eyepiece was removed and a small camera fixed on its tube, and with its adjustment the focal image was obtained on the ground glass of the camera. . . . . .

Plates Nos. 8, 9, 10 and 11 were exposed during the totality, but not the slightest vestige of an image was obtained, evidently from want of exposure: three of them were exposed 6 seconds, and one 7 seconds only. I believe good negatives of the corona might have been obtained with an exposure of 15 seconds.

The nitrate bath was nearly neutral, the collodion Thomas's for iron development iodized 6 days. The Developer, 10 gr. of pro. sul. iron, 15 minims gla. ac. acid, and 15 minims alcohol, to the ounce of water. On the sensitive plates exposed for the corona I first used the above mentioned iron developer; failing to obtain an image with that, I used an iron developer of 30 grs., but no corona made its appearance; so as a last resource, I used a very strong pyrogallic developer, but it was all in vain,—I could not obtain the faintest image.

Eclipse of 1869, Aug. 7th.

The photograph of the corona taken at Shelbyville shows two broad rifts in the neighbourhood of the sun's poles, and four great groups of structure in the north-west, south-west, south-east, and north-east quadrants. Plate 4 was made from paper copies of the Shelbyville photograph which were sent to England in 1870 and 1871. It has been oriented by means of the prominences, which were identified with those shown on copies of the Ottumwa photographs.* The original negative of the Shelbyville photograph is now in the possession of Prof. Pickering, at Harvard College Observatory. From a cursory examination of this negative, which I made during a visit to Harvard in 1878, it was evident that a great deal of structure was recognizable in the original negative which is not shown in the steel plate published in vol. vi. of the "Annals of the Harvard College Observatory." A good deal of structure is also to be seen in some of the other negatives taken at Shelbyville during totality, which were only exposed for a few seconds. Accurate drawings of the structure to be seen in these photographs under suitable illumination are much to be desired. The Shelbyville photographs.

Some of the brighter structure in the lower parts of the corona can also be seen upon glass copies of the Ottumwa photographs which have been sent to the Royal Observatory, Greenwich. The lower parts of the great groups of synclinal structure shown in the Shelbyville photographs can easily be recognized in the copies of the Ottumwa pictures; and no doubt still more detail is shown on the original negatives, which were taken in an enlarged image of 2¼ inches diameter formed by means of a two-lensed eyepiece, with a telescope of six inches aperture. The Ottumwa photographs.

It is difficult to institute a satisfactory comparison between the brightness of the corona visible during this eclipse and that seen during the eclipse of 1868. Col. TENNANT's 1868 photographs were taken in the prin-

* According to the drawing of the prominences made from the Burlington photographs, which was published in the October number of the *Journal of the Franklin Institute*, the position of the north pole of the sun's axis should be some 5° further to the east. Having regard to the care which Prof. MAYER and Dr. GOULD expended in determining the position of the wires for the Burlington photographs, it is to be regretted that the position of the north point, as given in the Burlington photographs, was not adopted in determining the position of the sun's axis at the time that plate 4 was made.

Brightness of the coronas visible during the eclipses of 1868 nd 1869.

cipal focus of a 9-inch silver-on-glass reflector of about 6 feet* focus, but the corona appears to have been covered by a thin veil of cloud during totality. One of Col. TENNANT's plates was exposed for 10 seconds, but only very slight traces of the corona were obtained—decidedly less than can be seen in the copies of the Ottumwa photographs, which were exposed for 6, 12, and 16 seconds respectively. SUTTON's attempt to photograph the corona was made in the principal focus of a 3½-inch refractor of 66 inches focal length; but though the sky appears to have been clear during totality, and the sun was at a considerable altitude above the horizon, "not the slightest vestige of an image" of the corona was obtained with exposures of 6 and 7 seconds.† There is, however, no proof that the instrument was properly directed to the sun during totality. With a telescope of 66 inches focal length, the image of the dark moon in the principal focus would have been more than half an inch in diameter, and it seems improbable that images of the prominences on such a scale should have been overlooked, especially when the remarkable size of the prominences which were visible during the eclipse of 1868 is taken into account.

Groups of synclinal structure.

In addition to the evidence as to the synclinal nature of the principal groups of coronal structure to be derived from the photographs, it will be noticed that EASTMAN's drawing shows four great conical groups of synclinally curving rays. HILL and HOUGH speak of structures in the corona which reminded them of the petals of a flower, and MURRAY describes five great sheaths of rays, while DIXWELL speaks of the rays being grouped into "four great pencils or cones."

* This information is derived from Mr. Browning.

† If we speak of the intensity of the light of an image of the corona in the principal focus of an object-glass whose focal length is ten times its aperture as 1, then, neglecting the absorption due to the lenses of the eyepiece, the intensity of the image thrown upon the photographic plate by the instrument with which the Ottumwa photographs were taken was only ·068; while with Col. TENNANT's instrument, if we neglect the loss of light due to the flat and the presence of the cloud, the intensity of the image thrown upon the plates was about 1·5. The veil of cloud over the sun's place as seen from Guntoor during totality cannot have been very dense, as the images of the prominences are perfectly sharp, and there is no luminous haze around them extending on to the dark moon. The sun's altitude as seen from Guntoor during totality was more than 52°, while as seen from Ottumwa it was only about 24° 30′ above the horizon. The actinic rays of the corona, therefore, probably suffered considerably greater absorption in passing through the earth's atmosphere at the latter station. For SUTTON's instrument the intensity of the image in the principal focus would be ·285.

SCHOTT'S drawing of the corona shows four principal groups of coronal structure, which he refers to in his description as "cusps or brushes of light" and "bundles of rays." These four principal groups of coronal structure correspond with the four groups shown in the Shelbyville photograph, and seem also to have been observed by SIMON NEWCOMB, HIMES, PICKERING, PIERCE, and BLAKE, and probably also by HOUGH, DIXWELL, CUTTS, and EASTMAN; though the two latter observers each draw the four principal groups of structure as forming a roughly symmetrical rectangular cross with arms about equally inclined to the horizon.

Four principal groups of structure.

Most of the observers draw or describe the corona as quadrilateral in outline, the diagonals of the quadrilateral corresponding with the axes of the four principal groups of structure, and making angles of about 45° with the sun's axis. A fifth somewhat less conspicuous group of structure is also drawn by SCHOTT in the eastern equatorial region, and seems to have been observed by PICKERING and HOUGH, and probably also by HIMES and MURRAY. HIMES speaks of it as in the south-west region, but he is probably speaking of the unoriented image as seen in an inverting telescope.

Quadrilateral drawings.

ABBE'S description of the spiral structure of conical masses observed by him in the south-west quadrant of the corona is curious, and deserves comparison with the somewhat similar observation of WINTER, made during the eclipse of 1860. HIMES and PICKERING also refer to the "curled," "twisted," and "spiral" structure of the corona; but it is evident that PICKERING refers to an arrangement of the rays about the sun's centre. The two masses of coronal structure like comets' tails, observed by LANE, appear to have been parts of the great group of structure in the south-eastern section of the corona.

Spiral structures.

It will be seen that the Shelbyville photograph indicates the existence of broad rifts in the polar regions which were probably partly filled up by faint coronal matter, for they do not seem to have been noticed by any of the observers.* The broad rifts, however, indicate that the synclinal zones were more depressed towards the equatorial regions than in

Rifts in the corona.

* Except possibly SIMON NEWCOMB and CUTTS. From SIMON NEWCOMB'S description one would gather that there were similar shallow parts of the corona in the equatorial regions. CUTTS' description of the shallowest part of the corona being in the "lower left hand quadrant" is not sufficiently definite to enable us to identify it with the southern rift.

Corona of 1869 intermediate in type between the coronas of 1868 and 1871.

the corona of 1871. On the other hand, it seems that the synclinal zones occupied higher heliographic latitudes than in the corona of 1868. Wolf gives 77·6 as the monthly relative number of sun spots for August 1869, proving that the solar activity was considerably greater than at the period of the eclipse of 1868, though much less than at the periods of the eclipses of 1870 and 1871.

Prof. Cleveland Abbe. 42 34 N. 96° 15′ W. } Sioux Falls City, 7th Aug., 1869.

"Nature," Vol. v., pp. 367, 368. *See also* "American Journal of Science and Arts," Vol. iii., April 1872.

My own attention was expressly given to the structure of the corona and coronal streamers, for which purpose I used the full aperture of an exquisite six-inch objective. . . . .

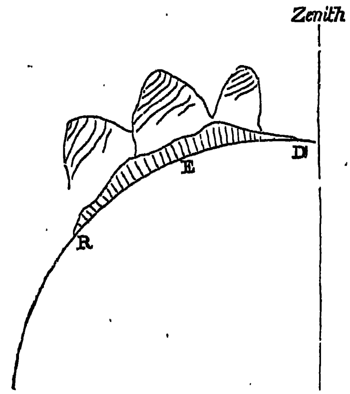
No sooner had totality begun than, after sketching in most of the prominences as points of reference, I viewed the corona without darkening glasses, and with a magnifying power of probably 120 diameters. . . . .

As seen through my inverting telescope, the structure of the large protuberance on the right-hand lower limb was well made out. The neighbourhood of the sun was examined to a distance of its own diameter (a radius of possibly one degree from the sun's centre), but no trace of the coronal rays as they were seen by others of my party. The evidence as to the existence, shape, and positions of these streamers, as given by my six assistants, was conclusive as to their actual appearance, with the usual variations as to details. That they were not detected by the six-inch glass was probably due to their diffused light and the small field of view.

On the apparent upper and left-hand limb of the sun, the six-inch glass showed the long series of red prominences depicted in the photographs published by the Naval Observatory. Above the greater portion of the arc of the sun's limb thus covered, and extending somewhat farther to the right, appeared to rise up three, and possibly more, conical masses of pearly light.

These were distinctly contrasted against the light diffused as the background of the field of view, and there was every evidence that they had an identical structure and cause. The outline of each of the pearly mountains was that of a rounded cone, as shown in the drawing—exactly

resembling the kilns used in some branches of pottery and other manufactures. The apices of the cones were blunted or truncated, and not well defined; the outlines of the sides of the cones were quite sharp down to within a few minutes of the sun's limb, when all three appeared to begin to lose their distinctive characteristics.



Drawing by Cleveland Abbé of structure observed in the corona of 1869, Aug. 7th.*

The height of the apices above the limb varied between one-half and two-thirds of the solar radius; the diameters of the bases of the cones were probably included between seven and three minutes. Each apex was of a slightly dusky shade compared with the body of the cone.

The most interesting feature was an unmistakable striation upon the surface of each cone; the striæ apparently twisting spirally around up to the apex opposite to the movement of the hands of a watch, as represented in the accompanying drawing. I noticed no coloration of these striæ other than their darker hue. . . . .

The pearly cones were on that limb of the sun from which the moon was moving, and the details were every moment becoming more distinct, when the growing height of the bank of red protuberances was followed by the too speedy apparition of the glowing sun beneath.

Chagrin at the loss or imperfect observation of the third contact caused me to forget to note whether the three cones continued in view for any number of seconds thereafter. From the time of first recognising the pearly cones, until their disappearance, probably thirty seconds elapsed (I am writing without my note-book or other aid to memory), and I did not note any change in the appearance of the striæ.

The middle one of these cones caught my eye more especially, and the impression was that the other two, especially that on the right, were some distance behind it, or possibly obscured by a cloud of haze in the

* Made from the woodcut given in *Nature*. The conical masses observed would be in the south-west section of the corona. (The woodcut evidently corresponds with the image seen in an inverting telescope.) Assuming the time of mid-totality at Sioux Falls to be $4^h\ 28^m\ 1^s$ local true time, the south pole of the sun's axis would be $36°\ 13'$ to the right of the line marked zenith.

solar atmosphere. At the time it seemed to me that I saw in the central cone a column of smoke and hot gas ascending high above the area of red flames then visible on the surface of the sun, and that the other two cones corresponded to other areas of red flames behind.

Mr. S. Gilman. 96° 8′ 42 W. } 42° 47′ 30″ N. } ST. PAUL JUNCTION, IOWA, 7th Aug., 1869.

Appendix II. to the "Washington Observations" for 1869.

(p. 180.) The general outline of the corona was a trapezium, with the widest side to the south-east. There were also lesser projections on the four sides, as well as several small indentations. The longest masses of light coincided very nearly with the north and east * points, at the middle of totality. Mr. FARRELL also noted the same peculiarity.

Prof. Simon Newcomb. 41° 35′ 4″ N. } 37′ 12″ W. } DES MOINES, 7th Aug., 1869.

Appendix II. of the "Washington Observations" for 1869.

(p. 9.) Leaving the telescope, I returned to naked-eye observations. Looking directly at the corona, there was no actual appearance of striation, but it seemed to be of a jagged outline, extending out into four sharp points, nearly in the horizontal and vertical direction, while midway between these points the serrated edge hardly seemed to extend beyond the body of the moon. The greatest distance to which the extreme points seemed to extend did not exceed a semi-diameter of the moon, and there was nothing like long rays of light extending out in any direction whatever. When I turned my head, the points did not seem to turn with it. Still I experienced a singular difficulty in judging accurately either of the number or direction of the jagged points, or of the extent to which they might be

* A highly coloured lithographic copy of Gilman's drawing is given on Plate xii. of the *Washington Observations* for 1869. It is evident, from a comparison of the prominences with those shown in the plate from the Burlington photographs, published in the October number of the *Journal of the Franklin Institute* for 1869, that Gilman's drawing corresponded to the unoriented image of the corona as seen in an inverting telescope. The general outline of the brighter part of the corona, as shown in Gilman's drawing, is quadrilateral, the greatest extension of the brighter area being from the centre of the right hand limb and from below the moon's disc, which would correspond in the uninverted oriented image with the north-east and south-east sections of the corona.

optical illusions, produced by the differences in the height and brilliancy of different parts of the corona.

The green glass, however, settled the latter question. Seen through this medium, the corona consisted simply of four or five prominences, extending around the moon, smooth in their outline, shading off by imperceptible gradations, and rising to different heights, the greatest height not exceeding four or five minutes. The accompanying sketch * gives a general idea of the impression produced by the view through the coloured glass. I have no doubt that the serrated appearance of the corona, and the pointed rays, were purely optical results of the irregular heights of the prominences.

Prof. J. R. Eastman. 41° 35′ 2″ N. 93° 37′ 17″ W. DES MOINES, 7th Aug., 1869.

Appendix II. of the "Washington Observations" for 1869.

(p. 105.) The corona seemed to be composed of two portions, both visible to the naked eye, in which, with the small instrument which I used, I was unable to trace any similarity of structure.

The portion nearest the sun was about 1′ high, forming nearly a continuous band about the sun, and appeared to be a mass of nebulous light, resembling in structure the most brilliant, irresolvable portions of the milky way. Its colour was silvery white, and, like its density, appeared the same throughout its whole extent. The outer portion consisted of rays of light arranged in two different ways. In five places they were arranged into groups resembling star points composed of slightly convergent and radial rays, but elsewhere were disposed as radial lines. Between the protuberances Nos. 4 and 5 † scarcely any corona was observed.

Four ‡ of the star points project farther from the sun than the ordinary radial lines, and give the contour of the corona the form of a trapezoid.

* The sketch has not been reproduced, as it only professes to give "a general idea" of what was observed.

† Protuberances Nos. 4 and 5 were in the eastern equatorial region.

‡ A woodcut is given at p. 105, and two coloured lithographic plates at the end of the volume (Figs. 1 and 2, plate ix.) In the woodcut four conical groups of synclinally curving rays are shown. The drawing is evidently intended to represent the corona as seen in an inverting telescope, and the four groups of rays are situated so as to form a roughly symmetrical rectangular cross, the arms of which are about equally inclined to the horizon; so that in the oriented

Mr. J. Homer Lane.

41° 35′ 4″ N. } DES MOINES,
93° 37′ 12″ W. } 7th August, 1869.

Appendix II. to the "Washington Observations" for 1869, p. 169.

I turned my attention to the agglomerations of white light in the corona; and fixed upon two of these which were remarkable for their small size and the comparatively dense accumulation of light in them. These were situated about 80° from the vertex towards the right,* as seen inverted in the telescope. In appearance they might well be compared to small telescopic comets, with tails of some length, but without a head, and with no distinct indication of a head at one end rather than the other. They were not far from radial in direction relatively to the sun's centre—whether exactly so I did not remark at the time—but appeared completely isolated, and had their origin above the limb of the moon. [Mr. Homer Lane subsequently estimated the length of each to be about 130″.]

Prof. Charles F. Himes.

41° 2′ N. } OTTUMWA, IOWA,
92° 23′ W. } 7th August, 1869.

"The Journal of the Franklin Institute," Oct. 1869, p. 278.

The corona approached much more nearly in regularity the four-rayed form generally given, and which had always seemed idealized or conventional. The S.W. ray was, however, unequally subdivided, with the smaller part towards the north. The whole seemed of a fibrous, slightly curled or twisted character, somewhat like a cirrous cloud, and of silvery whiteness.

picture two of the groups would be in the neighbourhood of the sun's poles and the other two in the equatorial regions. This does not correspond with the position of the chief groups of structure as drawn and described by most of the other observers. But it does not seem probable that the drawing has been turned round as a whole, for a comparison of the prominences, which, though rather roughly given in the woodcut and lithographic plate, can be easily identified with those shown in the photographs, proves that there is no serious error in the orientation as far as regards the prominences.

* Taking the time of mid-totality at Des Moines as $4^h\ 40^m\ 29^s$ local true time, the sun's axis would have been 37° 20′ to the right of the vertex. The structure referred to was consequently in the south-eastern section of the corona, at a distance of about 43° from the sun's axis.

Prof. E. C Pickering. 40° 57′ N. } 93° 38′ W. } MOUNT PLEASANT, IOWA, 7th August, 1869.

"The Journal of the Franklin Institute," Vol. lxxxviii., p. 285.

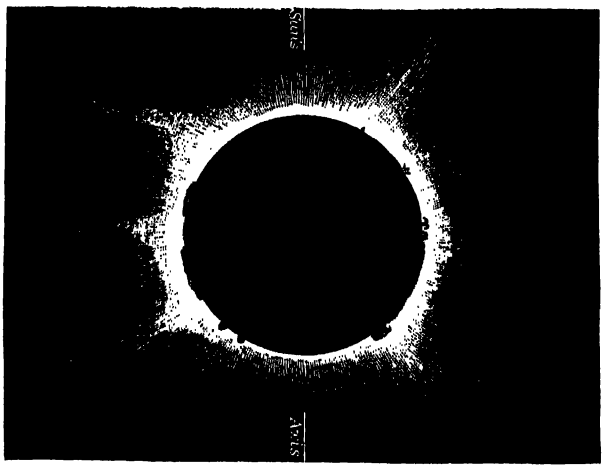
Instrument.—A small telescope, magnifying ten diameters.

A pocket telescope, magnifying about ten diameters, was used. It was tied to the back of a chair by a piece of cloth just tightly enough to make it remain in whatever position it was placed. The corona appeared to be an irregular four-pointed star, with, of course, a black centre. Two of the rays were nearly vertical, and two horizontal, the left-hand one pointing somewhat downward, while between it and the lower ray was a fifth smaller point. Its texture resembled the ragged edge of a thunder-cloud, or the crest of a wave torn by the wind. The striæ were not radial but spiral, as if the sun had been turned in such a way that the upper edge moved towards the east.

Mr. Chas. A. Schott.
Mr. F. B. Meek. 39° 49′ 2·5″ N. } 89° 38′ 24″ W. } SPRINGFIELD, ILLINOIS, 7th August, 1869.

"Reports of the United States Coast Survey," Appendix No. 8 to Report for 1869, p. 37.

In the accompanying sketch I have tried to produce a faithful picture of the corona and prominences during totality. It is drawn relatively to scale. . . . The corona appeared white, with the slightest mixture of a very faint amber-coloured warmer tint. . . . The positions of the prominences are from our photographs, and the outline of the corona



Meek and Schott's drawing of the corona of 1869, Aug. 7th.*

* The above woodcut has been made from a water-colour drawing, kindly forwarded by Mr. Schott. It has been oriented from the vertex. Assumed time of mid-totality $5^h\ 1^m\ 12^s$ local true time. Sun's axis 39° 13′ to the right of the vertex. This agrees with the position of the sun's axis as marked by Mr. Schott on his drawing given in the plate published in the U. S. Coast Survey Report for 1869.

Schott's report. from the experienced pencil of Mr. F. B. Meek, of the Geological Survey of Illinois, who kindly consented to attend to this phenomenon. In general, the outline of the corona was quite well defined, and to some presented five, to others (perhaps the majority) four cusps or brushes of light. It was striated, and extended all round the covered sun; to the naked eye the maximum extent of the bundles of rays was nearly three-fourths of the sun's radius, but in general the coronal development was no greater than about one-fifth of the radius.

The accompanying sketch is intended to exhibit the symmetrical relation of the corona to the sun's equator. There are two (principal) bundles of rays to the west, in about 52° heliographical north and south latitude, and two (principal) bundles of rays to the east, in about 32° north and south latitude, with a feebler development of rays between the latter and over the equatorial region. The rays do not converge to the sun's apparent centre.

Mr. R. McLeod. 39° 49′ 2″ N. / 89° 38′ 24″ W. } SPRINGFIELD, ILLINOIS, 7th Aug., 1869.

"Reports of the United States Coast Survey," Appendix 8 to Report for 1869.

(p. 45.) From the outer rim of the corona bright white rays emanated on every side, but their length was greatest in four directions. The four *arms* of rays were of unequal length, that in the south-east quadrant being the longest. I took especial pains to estimate its length, and could trace it to the distance of nearly two diameters of the moon. The axis of this ray made an angle of about 20° with the vertical.* This angle did not change with a slight motion of my glass. The end of the longest ray was slightly curved towards the vertical.

Prof. J. M. Peirce. 39° 49′ 2″ N. / 89° 38′ 24″ W. } SPRINGFIELD, ILLINOIS, 7th Aug., 1869.

"Reports of the United States Coast Survey," Appendix 8 to Report for 1869.

* A lithograph from McLeod's drawing of the corona is given in the Coast Survey volume (plate xxv., fig. 12). The *arms* or groups of rays referred to spring from broad bases, and terminate in tapering points. There are four of these groups of rays, which are situated in opposite quadrants and form a very irregular cross. They do not correspond satisfactorily in position with the principal groups drawn by Schott.

(p. 41.) The corona impressed me as distinctly cruciform, the principal projections occurring near the north, south, east, and west points. But these projections had not the character of rays, such as are seen in the phenomenon called "the sun drawing water," but were irregularly curled, the whole resembling somewhat the corona occasionally seen in the aurora borealis.

President Hill. 39° 29′ 10·5″ N. 88° 23′ 0″ W. MALTOON, ILLINOIS, 7th Aug., 1869.

"Journal of the Franklin Institute" for Jan. 1870, p. 67.

The corona appeared to us a white ring of 4 or 5 minutes in breadth, with white rays 30 to 35 minutes in length, and a few white petals 6 or 8 minutes in length, one of which, on the right hand upper limb, was curved. No change was observed in the corona, during the total phase, except that one of us thought there was a tremulous flashing at the instant before the reappearance of the sun.

Prof. David Murray. 39° 29′ 10·5″ N. 88° 23′ 0″ W. MALTOON, ILLINOIS, 7th Aug., 1869.

"Journal of the Franklin Institute," Jan. 1870, p. 63.

Surrounding the dark body of the moon was a crown of light, with rays shooting out, in five great sheaths, to a distance equal to the sun's diameter.

Prof. G. W. Hough. 39° 29′ 10″ N. 88° 23′ W. MALTOON, ILLINOIS, 7th Aug., 1869.

"The Total Eclipse of August 7, 1869," (Hough,) p. 15.

In immediate contact with the solar disc it (the corona) appears as a clear silvery light, as bright as the brightest part of an aurora, and somewhat resembling it in consistency. Farther out it appears streaked with pencils, radiating in the direction of the centre. These rays are more especially noticeable at five points of the circumference, two of them pointing upwards and outwards, and three having a general downward direction. These prongs could be traced through a distance even exceeding the diameter of the sun, and near one of them was visible a curved

mass of light, in shape resembling the petal of a flower. On the upper edge of the disc was plainly seen an arch of light, parallel with the edge, and within the boundary of the corona.

Prof. S. P. Langley. 27° 2′ 29″ N. 86° 15′ 18″ W. OAKLAND, KENTUCKY, 7th Aug., 1869.

"Reports of the United States Coast Survey," Appendix 8 to Report for 1869.

(p. 82.) The corona was very notably different from my anticipation, being visible through the darkening glass as a halo close to the sun, whence radiated a number of brushes of pale light, some about the solar diameter (perhaps less) in length, not noticeably curved, and suggesting at the time a comparison with the auroral streamers; though by this I do not mean to necessarily imply apparent motion.

Mr. F. J. Blake, Jun. 38° 12′ 45″ N. 85° 13′ 22″ W. SHELBYVILLE, 7th Aug., 1869.

"Reports of the United States Coast Survey," Appendix No. 8 to Report for 1869.

(p. 30.) With the extinction of the last ray a startling change took place. The corona, of which, up to this moment, there had been positively no indications, now appeared as an extremely soft white light, surrounding the sun and extending from it, in all directions, to a distance of at least two-thirds of its diameter. There was no appearance of rays, nor was there any sparkling light; it had, infact, a perfectly dead or "set" look. Its general form was irregular and somewhat similar to that of the rough sketch,* which is copied from one I made at the time.

Mr. R. D. Cutts. 36° 35′ 49″ N. 82° 11′ 13″ W. BRISTOL, TENNESSEE, 7th Aug., 1869.

"Reports of the United States Coast Survey," Appendix No. 8 to Report for 1869.

(p. 7.) The corona appeared to be a broad circular band of silver

* The outline of the corona is represented in the sketch as a quadrilateral with rounded corners. The diagonals of the quadrilateral are nearly horizontal and vertical upon the page.

coloured light, with an inner brighter rim, and with rays extending from different points, but very irregular in length and profusion. By far the longest rays were visible about 48° to the left of the vertex, or where the sun disappeared; and their length was estimated at the diameter of the moon. The rays on the opposite side of the circle were the next longest, being about half the length of the first mentioned. The lower left-hand quadrant appeared to be comparatively bare.*

Mr. J. J. Dixwell. 38° 12′ 45″ N. 85° 13′ 22″ W. SHELBYVILLE, KENTUCKY, 7th Aug., 1869.

"United States Coast Survey Report" for 1869, Appendix No. 8, p. 23.

With the naked eye the corona appeared like a rim of great brilliancy encircling the moon, gradually decreasing in brightness as the distance from the moon's edge increased, and fading wholly away at the distance of half a diameter. . . . Through the glass the appearances were very different. The corona spread out in rays of very irregular length, the longest of which extended more than a diameter from the moon. One observer thinks that the maximum length was one diameter and a half. Generally the rays radiated from the moon's centre, though there were some deflections. They were grouped in four great pencils or cones of irregular size, connected by shorter rays, forming together a continuous halo.

Attempts to Photograph the Corona of 1869, *August 7th.*

Prof. F. Himes. 41° 2′ N. 92° 23′ W. OTTUMWA, IOWA, 7th Aug., 1869.

"Journal of the Franklin Institute," Oct. 1869, pp. 276—280.

On our arrival (at Ottumwa), on Wednesday evening preceding the 7th, we found a very convenient shelter shed, with sliding roof and photographic room, erected under instructions from Prof. COFFIN.

* The lower left-hand quadrant would correspond with the region of the sun's southern pole. The ray 48° to the left of the vertex would be in the eastern equatorial regions.

Himes' report of photographic operations.

The telescope* was set up next day upon a cross of timber firmly let in the earth. The clockwork, not of very superior construction, was found to have become deranged by carriage; but fortunately the skill and experience of Mr. Zentmayer were available, and it was put in as good running order by him as it was susceptible of, otherwise we should have lost the opportunity for taking the totality negatives with a length of exposure sufficient to give the amount of detail and corona we obtained.

It was deemed advisable, however, that Mr. MOELLING should pay exclusive attention to the clock during the progress of the eclipse, in order to detect and correct any irregularity that might occur. . . . .

The morning of the 7th found the sky overcast; but gradually, with a dry wind from the east, the clouds gave way, until at noon not a trace of cloud or haze was to be seen. These few hours were improved by determining the actinic focus with great accuracy.

The photographic preparation was exclusively managed by Messrs. BROWNE and BAKER. . . . .

During totality the full aperture was used, and exposures of 6, 12, and 16 seconds given, producing negatives of exquisite sharpness and detail, including a portion of the corona.†

The general plan of exposure was to obtain five negatives, if possible, near the contacts, and three near the beginning and end of totality, and at intervals of five and ten minutes during the other phases; and we have reason to be satisfied with the results.

The one immediately preceding totality displays the limb of the sun beautifully cut up into Baily's beads, and the one taken at the instant of the close of the total phase received the first rays of the emerging sun, but is of interest as showing in this connection the red prominences. On this plan thirty-four excellent accurately timed negatives were obtained.

* This instrument was the Gettysburg telescope, of 6 inches aperture and $8\frac{1}{2}$ feet focal length. The photographs were not taken in its principal focus, but in an enlarged image of about $2\frac{1}{8}$ inches diameter, formed by means of an eyepiece of two lenses, designed by Mr. Zentmayer. The particulars of its construction, together with the reasons for not adopting the the ordinary Huyghenian form, will be found set out in the report of Prof. HENRY MORTON, at pages 204, 205, of the *Journal of the Franklin Institute*, for Sept. 1869.

† Only traces of the brighter structure of the lower parts of the corona are shown upon the plates; there is enough, however, to indicate the position of the edges of the great groups of structure in the north-east, south-east, south-west, and north-west sections of the corona.

[The annexed schedule gives the times of exposure during totality, as noted by Prof. C. F. Himes.]

NO.	TIME OF EXPOSURE.	EXPOSURE SLIDE.	REMARKS.
17	$10^h\ 57^m\ 36\frac{1}{2}^s$, for a fraction of a second.	Slit $\frac{1}{40}$th of an inch wide.	Baily's Beads.
18	,, ,, for about 6 seconds.	Circular aperture, size of eyepiece.	
19	,, ,, ,, 12 ,,	,, ,, ,,	
20	,, ,, ,, 16 ,,	,, ,, ,,	
21	$11^h\ 4^m\ 15^s$, close of totality and after totality.	,, ,, ,,	Fogged a little.

Mr. J. C. Browne. 41° 2′ N. 92° 23′ W. OTTUMWA, IOWA, 7th Aug., 1869.

"Journal of the Franklin Institute," Nov. 1869, p. 355.

Following the advice given by Mr. WARREN DE LA RUE, in his report on the eclipse of 1860, I used fused nitrate of silver in making up the nitrate bath, in the proportion of 45 grains of silver to the ounce of distilled water, acidulated with 6 drops of nitric acid C.P.

One gallon and a half of filtered silver solution was allowed to each party, carefully packed in two-gallon demijohns in separate boxes; one gallon of distilled water being included in each box, also extra silver in case of accident. Five glass dipping baths, holding 20 oz. of solution each, were thought to be sufficient, each bath enclosed in a wooden box, with a cover to exclude light and dust, and hard rubber dippers coated with paraffine.

Various samples of collodion were made up, but none gave such excellent results as the following mixture :—

Alcohol	1 pint.
Ether	1 pint.
Cotton	4 grains.

Excited with

Iodide of ammonia	5 grains.
Bromide of magnesium	$2\frac{1}{2}$ grains.

Developing solution was made in the proportions of 80 grains of proto. sul. of iron to the ounce of water. No acid was added unless

Browne's report of the preparations for photographing the corona at Ottumwa.

desired for immediate use. The solution was then reduced to the strength of 20 grains of iron to the ounce of water, and the addition of 2 drams of acetic acid, No. 8, to each ounce.

Cyanide of potassium was used for fixing, and a liberal allowance of chemicals was included with each outfit, also collodion vials, funnels, filter-paper, brushes, etc.

All the articles were packed in boxes, with the name of the respective telescopes marked upon the outside. I was stationed at Ottumwa, with the section of Prof. HIMES, and took charge of the coating of the plates, while Mr. BAKER developed them. Our chemicals all worked in the most satisfactory manner.

No re-development was necessary. In most of the exposures the picture came up almost too rapidly, rendering it necessary to have cold water close at hand to check further action. To gain time during the development of so many negatives, after the image was all out upon the plate it was washed slightly and placed in a bucket of water containing a few pinches of chloride of sodium.

During the eclipse, after totality as many as eight or ten plates were placed in the bucket at one time, collodion side towards the inside; afterwards the plates were washed and fixed. All the plates were numbered with a diamond and dipped with the number always in the same position.

Prof. Alfred M. Mayer. 40° 48′ 17″ N., 91° 4′ 0″ W. BURLINGTON, 7th August, 1869.

The Total Eclipses of Aug. 7th, 1869 (*reprinted from the* "Journal of the Franklin Institute," Oct., 1869).

(p. 3.) The equatorial was borrowed from the observatory of the Central High School, Philadelphia, and is by Merz and Mahler of Munich. It is of 9 feet focus and 6·42 inches aperture. . . . .

(p. 5.) The image of the sun was formed on the plate of the camera by the action of a negative eyepiece, the lenses of which were so placed by Mr. Zentmayer in relation to the object-glass, and to each other, that the diameter of the sun's image was 2·04 inches. . . . .

Mr. Zentmayer had so constructed the camera eyepiece that the image of a reticule of two spider threads, at right angles to each other, was formed on the plate with the image of the sun, and these threads

were so mounted that they could be adjusted respectively parallel and at right angles to the celestial equator, and thus fix on the photographs the positions of the sun and moon, and give the position angles of points on the surface and periphery of the sun. This adjustment I deemed of great importance, as without it we could not obtain the position-angles of contact nor the positions of the protuberances during totality. The lines are nearly as sharply defined on the pictures of totality as on those taken during partial phase. The adjustment was made as follows: the camera was firmly screwed to the telescope, and the focussing tube was moved until the images of the sun and threads of the reticule were brought to exact focus on the ground plate.

A well-defined spot in the south-west quadrant of the sun was now made to travel along the thread by clamping the telescope in right ascension, and the reticule plate revolved until the spot was accurately bisected during all its progress across the field. The telescope was then unclamped in right ascension (still remaining clamped in declination) and moved around the polar axis so that the spot ran along the thread; it was found to be bisected throughout all its transit. Dr. GOULD, at my request, now examined the adjustment, and pronounced it precise.

[Five photographs were taken during totality with exposures of 5^s and 7^s; they show the prominences with great distinctness, but judging by glass positives which have been sent to England, only slight traces of the corona were obtained.]

Mr. Black. **Mr. Fitzgerald.** **Mr. Pourtales.**	39° 49′ 2″ N. 89° 38′ 24″ W.	SPRINGFIELD, ILLINOIS, 7th August, 1869.

"Reports of the U. S. Coast Survey," Appendix 8 to Report for 1869.

(p. 34.) Photographic pictures of the eclipse were obtained by means of an equatorially mounted refractor by Dollond, having about 6⅛ feet focal length, and a clear aperture of 4 inches. . . . .

(p. 35.) During totality the slit was opened to the full size of the picture, but, as the photographs show, the sun was but very imperfectly followed by hand, making a series of superimposed pictures. [It seems that only images of the prominences were obtained, with no trace of the corona.]

Prof. Joseph Winlock. 38° 12′ 45·36″ N. 85° 13′ 22″ W. SHELBYVILLE, 7th Aug., 1869.

"United States Coast Survey," Appendix No. 8 to Report for 1869, p. 11.

[In the photographic department] I was assisted by Mr. Wipple, Mr. George D. Clark, Mr. John Pendergrast, and also by Mr. Williams, a photographer of Shelbyville, who kindly offered his services. The instrument employed was the small equatorial of Harvard College Observatory, which I had fitted up for this purpose. It has a clear aperture of 5½ inches, and a focal length of about 7½ feet; and it is provided with an excellent driving clock.

In making preparations for the use of photography in these observations, I decided to take the pictures of the sun in the principal focus of the object-glass. I rejected the method of enlarging the image with an eyepiece, adopted by Mr. De la Rue in Spain, in 1860, and by American astronomers who were preparing to photograph the eclipse of 1869, because, my main object being to secure a good picture of the corona, I did not think it expedient to enfeeble the light by enlarging the image. Another reason in favour of this method is, that the distortion caused by the enlargement is avoided, and the pictures can be measured more satisfactorily with a micrometer. The camera was fitted with a slide near the image, for instantaneous exposure in taking the partial phases. During totality the slide was removed and the exposure was made by uncovering the object-glass. The results were very satisfactory. We succeeded in obtaining about eighty photographs during the eclipse, seven of which were taken during totality. One of these, with an exposure of about forty seconds,* gives a most satisfactory picture of the corona. I immediately recognised in this the fact that the corona was less in extent near the extremities of the sun's axis, and largest in the line of the equator. I have reason to think that this picture gives nearly all of the corona which can with certainty be considered as belonging to the sun.

* This is the photograph represented in plate iv.

Eclipse of 1870, December 22nd.

This eclipse took place at a period when solar activity as evidenced by sun spots was exceptionally great. According to WOLF, "the relative monthly number" for Dec. 1870 was 135·4. Period of great solar disturbances.

It will be seen from the evidence at our disposal that the corona visible during this eclipse was of great extent, both in the equatorial regions and in the regions of the sun's poles; but that it was probably more homogeneous in its lower parts than the coronas of 1869 and 1871, when the number and development of sun-spots was considerably less. The coronal structure, as well as being less striking as compared with the background on which it was observed, seems to have been somewhat less symmetrically arranged with respect to the sun's axis than in other coronas observed at recent eclipses. Great extent of corona.

The photograph taken by Mr. BROTHERS at Syracuse, with an exposure of only 7 seconds and an instrument similar to the instruments made use of at Baikul and Dodabetta in 1871, shows the corona extending to a much greater distance from the sun's limb, more especially in the polar regions, than the photographs taken in 1871.* This is the more remarkable when the cloudy state of the atmosphere at Syracuse during totality is taken into account, and it is remembered that Mr BROTHERS' instrument was stopped down by a diaphragm to only 3 inches—thus decreasing the intensity of the image thrown upon the photographic plate by nearly one-half. The exposures at Baikul varied from 10 seconds to 40 seconds, and at Dodabetta from 5 seconds to 20 seconds. The sun's centre was 22° 46′ above the horizon at the time of the exposure of the Syracuse photograph—that is, nearly 5° higher than at the two Indian stations. Comparison of the 1870 and 1871 photographs.

The sharpness of the edges of the rifts in the Syracuse photograph proves that the great extent of the corona, as shown upon the photographic plate, could not have been due to dispersion of the light of the prominences Rifts not due to clouds.

* The extent of the corona in the copies of the Java 1871 photographs is less than in the photographs of the Baikul or Dodabetta series, in which the corona does not extend to 27′ from the sun's limb; but in Mr. BROTHERS' 1870 photograph the corona extends to at least 40′ from the limb.

and brighter parts of the corona by clouds. Similar rifts are shown in the Jerez photographs, though unfortunately a diaphragm in the telescope with which Mr. WILLARD's photograph was taken cut off the outer parts of the corona.

The great rift in the S.E. quadrant.

The great rift in the south-eastern quadrant seems to have formed a very striking feature of this corona, and to have been either drawn or described by at least ten of the observers whose observations are given in the following chapter. The place of the rift corresponds very fairly in all the drawings, and is somewhat to the east of the position of the rift as shown in plate vi., which seems to indicate that the orientation which was adopted when plate vi. was made is some 15° in error,* and that the north pole of the sun's axis should lie more to the east. Considering the unsatisfactory manner in which the position of the sun's axis was determined in orienting plate vi., such an error is quite possible, and would necessitate a corresponding alteration of plate v., which, in the absence of data for determining the position of the Jerez photograph, was oriented to correspond with plate vi.

Orientation of Plate vi.

Observations of the Great Rift in the South-East Quadrant of the Corona.

Alex. B. Brown gives a drawing of the corona with an irregular outline, and a rift with curving sides, somewhat similar to the great rift shown in the photographs, but situated some 20° to the east of the position of the great rift as shown on plate vi.

F. H. Browne gives a quadrilateral drawing of the corona, with a V-shaped gap reaching down to the moon's limb about 20° to the east of the position of the great rift as shown in plate vi.

Hostage gives a drawing of the corona with a circular outline and a dark ray, of nearly the same thickness all the way down to the moon's limb. It lies a little to the east of the position of the centre of the great rift as shown in plate vi.

Hudson gives a quadrilateral drawing of the corona with a V-shaped rift, one edge of which is nearly radial, and the other slightly concave towards the dark space. The rift does not reach down to the limb of the dark moon, and is decidedly to the east of the position of the great rift in plate vi.

Perry noticed four parts of the corona where the light was less strong, but does not give their place.

* This assumption is also rendered probable by a comparison of the prominences shown on Mr. BROTHERS' negatives with the map of the chromosphere made by Mr. SEABROKE at Catania, at about 11.45 on the morning of the eclipse. Professor WINLOCK's orientation of the Jerez photographs, however, differs but slightly from the orientation which has been adopted for plates v. and vi.

Langley describes one "dark ray" which made an angle of 45° with the vertical.

Naftel gives a drawing of the corona with a circular outline, and a V-shaped rift situated some 20° to the east of the position of the great rift as shown in plate vi.

Young speaks of several straight dark streaks, extending out from the sun, but does not give their places.

Anson describes and draws a streamer which he saw in the south-west quadrant about 35° from the vertical. It seems probable that it corresponded to the great rift.

Watson gives a drawing with a rift in about the position occupied by the great rift on plate vi. But he estimates its position to be 142° from the north point, which would correspond to about 45° from the south pole of the sun's axis.

Mrs. Peirce describes "a long, dark, or rather delicate gray or steel-coloured ray, narrowest at the sun and widening as it went out." In her drawing she places this dark ray decidedly to the east of the position of the great rift.

Ranyard describes a ray with sharply defined edges, in the lower left-hand quadrant, which there can be little doubt corresponded with the great rift. Its position as given in the unoriented woodcut on p. 315 is rather to the east of the position which would be occupied by the great rift as shown in plate vi.

Hall describes "a deep opening" near to the "south-western point of the moon." It reached "nearly to the limb of the moon."

The outline of the corona is drawn as quadrilateral by MOULTON, F. H. BROWNE, HUDSON, GILMAN, and WARRINGTON SMYTH; while BAYNES, observers at San Lucar, observers at San Fernando, and a lady at Cadiz, draw the corona with rays or groups of structure corresponding to the diagonals of the quadrilateral outlines, and making angles of about 45° with the sun's axis. **Quadrilateral outlines.**

The circular outlines of the corona drawn by observers at San Lucar, HOSTAGE, and NAFTEL, and the approximately circular outline of A. B. BROWNE's drawing, evidently correspond to a much larger area than is comprised within the quadrilateral outlines; tending to prove that the general outline of the corona was circular, with a quadrilateral area of greater brightness within it. And judging by the Jerez photograph, the drawing of A. B. BROWNE, and the tracing of NORMAN, there was probably within the quadrilateral area an elliptical area of still greater brightness, the longest diameter of which about corresponded with the solar equator. **Circular outlines.** **Elliptic outlines.**

According to the evidence of Prof. NEWCOMB, the light of the corona was on the present occasion more homogeneous, and the structure within the field of the corona less striking, than in the corona of 1869. Prof. YOUNG states that the corona was more sharply defined in 1869 than in

Corona probably more homogeneous than on other occasions

1870; and a comparison of the photographs tends to show that the groups of structure in the corona of 1871 were more defined than on the present occasion. Allowance must be made for the fact that the corona was seen through cloud by many of the observers during this eclipse, but still it would seem that the structure cannot have been very striking. MOULTON and F. H. BROWNE speak of the corona as structureless. LANGLEY says that "On the closest scrutiny of the part nearest the sun, nothing was seen but a nearly uniform diffuse light." A. B. BROWNE speaks of very faint striations, and TACCHINI describes the corona as composed of very fine rays—"raggi sottilissimi."

The memory of observers who have seen other eclipses is not entirely to be trusted, as their judgment is likely to be affected by a comparison with the brightness of surrounding objects; and when the horizon is cloudy it seems probable that the illumination of objects within the zone of totality is much increased.

Comparisons of the Corona of 1870 *with the Coronas of* 1860 *and* 1869.

Young. In 1869 the corona seemed "more sharply defined than now, far more brilliant and more beautiful then, but striated with only fine lines without heavy markings." "On this occasion the corona appeared very indefinite in its outline."

Simon Newcomb. "Instead of the gorgeous spectacle I witnessed in 1869, I saw only the most insignificant corona. . . . . I could not see the slightest trace of bright or dark points, rays or filaments, the light everywhere seeming as soft and diffused as the zodiacal light. There were indeed, as in former eclipses, great differences between the extent and brilliancy of the corona at different points, but all the parts seemed to shade into each other by insensible gradations."

Warrington Smyth. The corona was "much less vivid" than I had seen it from Bruges in 1860.

Harkness. (The corona was observed through clouds, Prof. Harkness says.) "I do not think it was more than half or two-thirds as extensive as that which I witnessed at Des Moines in August, 1869.

Eastman. (Who observed from the same station as Prof. Harkness, says): "The structure of the corona appeared essentially the same as in 1869.

Groups of Synclinal Structure.

The observers at San Lucar and San Fernando represent the corona with four groups of structure forming a rectangular cross, the arms of

which made angles of about 45° with the sun's axis. It will be noticed that the axes of these groups correspond with the diagonals of the quadrilateral outlines drawn by MOULTON, F. H. BROWNE, HUDSON, GILMAN, and WARRINGTON SMYTH; and it seems probable that they formed the brightest parts of the corona, though they were not sufficiently conspicuous to strike all the observers; F. H. BROWNE mentions that there was a bright streamer corresponding to the north-east angle of the quadrilateral; and TUPMAN describes the lower left-hand part of the corona as being the largest and brightest. It will be noticed, too, that the rays drawn by BAYNES, and a lady at Cadiz, correspond in position with the above-mentioned groups. Arms of cross correspond with the diagonals of the quadrilateral outlines.

There is not much evidence to prove that these groups of structure were synclinal in their character. The edges of the groups as drawn by the observers at San Lucar curve slightly together,* and WATSON describes the structure of the brighter parts of the corona between the rifts as composed of radiating streams of light which it appears curved together in a synclinal manner; but these brighter parts as shown in WATSON's drawing do not correspond in position with the groups above referred to. TACCHINI also speaks of very fine rays "insiemi riuniti," but does not mention the position of the groups. Synclinal groups.

In the Syracuse negatives three conical groups of structure are shown upon the western limb, the central one of which is evidently composed of synclinal structure. If we adopt the amended orientation of these negatives (as suggested on p. 614), the central group would be slightly to the north of the western equatorial region, and the northernmost of the three conical groups would probably correspond in position with the north-eastern group as given in the drawings by BAYNES, the observers at San Lucar, and a lady at Cadiz. Synclinal groups in the Syracuse negative.

The south-eastern group of structure as shown in the last mentioned drawings, as well as in the drawings by BECKER, IGLESIUS, and THUILLIER, would then correspond with the bright mass with incurving edges lying between the great rift and the less conspicuous rift some 30° more to the north, corresponding to position angle 120° to 150° on plate 6. South-eastern group of structure.

The southern edge of the south-eastern ray or group of structure, as

* See also the synclinal group of structure drawn by CORALLO in the south-west section of the corona.

shown on the drawings by BAYNES, the observers at San Lucar and San Fernando, LASSALETTA, and a lady at Cadiz, would then correspond with the northern edge of the rift at about position angle 230° on plate 6.* But it is not clear what the north-eastern group of structure shown in the above drawings would correspond to on the photographs.

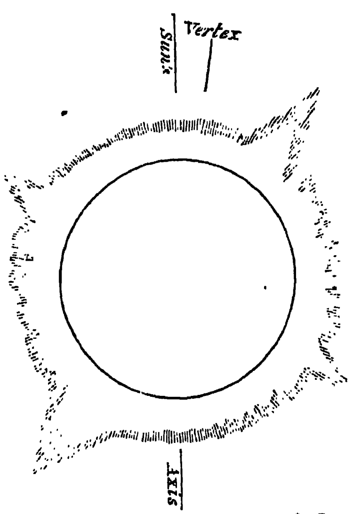
It is evident that, in addition to the four brighter groups of structure already referred to, there were other minor groups which tended to obliterate the symmetry apparent in the brightest parts of the corona. The most striking of these seems to have been the syclinal group in the western equatorial regions. Its outline can be traced on the copies of the Jerez photograph (see plate 5), and also in Lord Lindsay's negative. This group seems also to have been recognised by BECKER and THUILLIER, and possibly also by IGLESIUS and F. H. BROWNE.

Group of structure in the western equatorial region.

Mr. Baynes.

36° 40′ N. } HACIENDA DE TORRE-BREVA, SAN LUCAR,
6° 23′ W. } 22nd December, 1870.

MS. Reports of the 1870 Expedition.



Baynes' drawing of the corona of 1870, Dec. 22nd.†

Before making polarizing observations, I took a rapid survey of the phenomenon. As my field was so large (40′), I easily saw the whole of the corona and streamers. The corona was quadriform, with circular sides, but more extended in two directions, as in the figure, which was drawn afterwards simply from memory. The corona seemed to me to extend scarcely more than half the moon's radius from the limb; but I can place no reliance on this estimation, as I spent scarcely five seconds in the observation.

* The edges of this rift, as shown in the Syracuse photograph, are certainly not radial, but curve slightly away from one another.

† Made from a drawing accompanying Mr. Baynes' MS. report. Oriented from the vertex. Assumed time of mid-totality $23^{h}\ 51^{m}\ 36^{s}$ local true time. Sun's axis 8° 20′ to the east of the vertex.

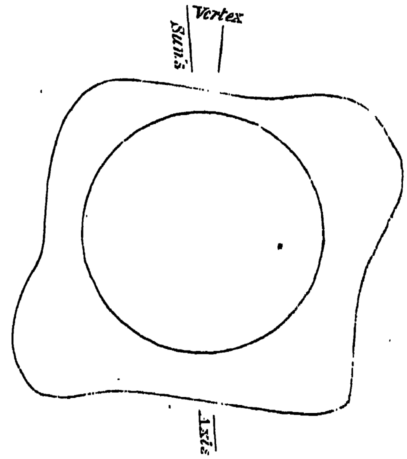
Mr. Moulton.

36° 40′ N. } Near San Lucar, Spain, 22nd Dec., 1870.
6° 23′ W. }

Quadriform corona; no structure.

MS. Reports of the 1870 Expedition.

I saw the corona through the clouds; it was a bright glow of a quadriform shape, the most distant parts being somewhat more than half a sun's radius from the black disc. No details of structure could be seen. I dropped the cap containing the dark glass, and observed through the telescope. It seemed to be merely a glow with no particular structure, except that those parts near the disc were distinctly brighter than the outer parts. A little later, just before the end of totality, I saw one part to the north-west of the sun, which seemed to me to be decidedly brighter than the rest; but that may have been due to the varying thickness of the clouds.



Moulton's drawing of the corona of 1870, Dec. 22nd.*

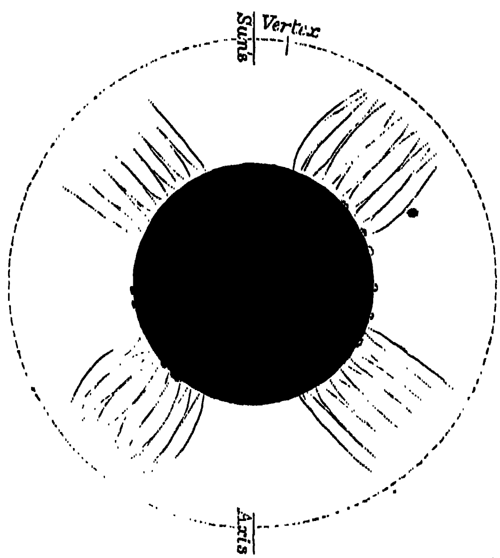
Observers in San Lucar.

36° 40′ N. } San Lucar, 22nd Dec., 1870.
6° 22′ W. }

"Anales del Observatorio de Marina de San Fernando," 1871.

(p. 8.) La Figura representa el aspecto de la corona en Sanlucar hácia la mediania de la totalidad, y se ha dibujado por medio de los croquis hechos sobre el terreno y de las descripciones de los diferentes observadores.

The figure represents the corona as seen at San Lucar about the middle of totality, according to the sketches and descriptions of observers.



Drawing by observers at San Lucar of the corona of 1870, Dec. 22nd.†

* Made from a drawing accompanying Moulton's MS. report. Oriented from the vertex. Assumed time of mid-totality 23h 51m 36s local true time. Sun's axis 8° 20′ to the east of the vertex.

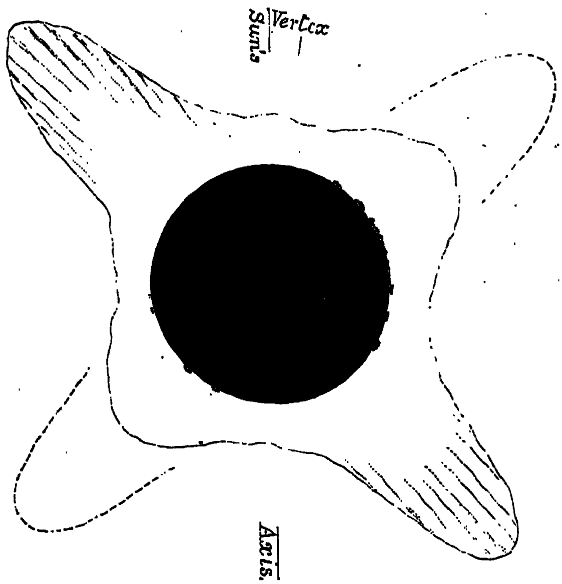
† Made from a coloured lithographic plate given in the "Anales del Observatorio de San Fernando" for 1871. Oriented from the vertex. Assumed time of mid-totality 23h 52m 36s local true time. Sun's axis 8° 7′ to the east of the vertex.

Senor Sanchez Marquez, and other observers at San Fernando. SAN FERNANDO, 22nd Dec., 1870.

" Anales del Observatorio de Marina de San Fernando," 1871.

The figure combines the details given in sketches made by Marquez and other observers at San Fernando, during the few moments that this corona was visible. The corona was formed of four irregular groups of rays, extending to a distance of about a lunar diameter to the N.E., S.W., N.W., and S.E.

(p. 6.) Los demás observadores aprovecharon los cortos momentos en que fué visible la corona, para hacer las observaciones que les estaban encomendadas, y el Señor Sanchez, Marquez Lizo, un croquis de ella sobre el cual y con los detalles en que se figaron los diferentes observadores, se ha formado la figura que es una reproduccion bastante aproximada del fenômeno, tal cual se viô en San Fernando, y que completa la descripcion sequiente.



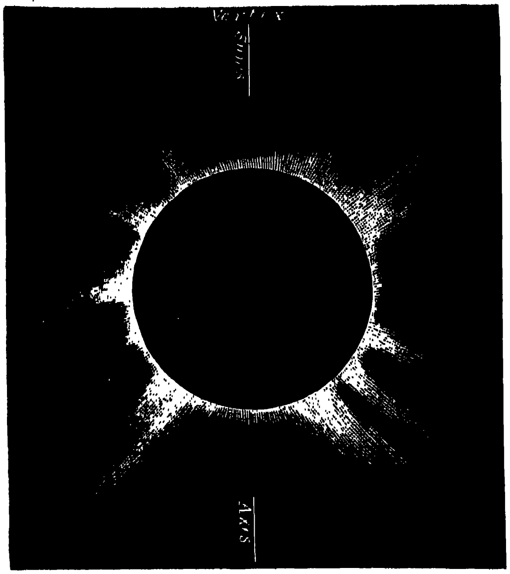
Drawing by observers at San Fernando of the corona of 1870, Dec. 22nd.*

La corona ó aureola, sobre la cual parecia destacarse el cuerpo de la luna, parecia estar formada de dos distintas partes; la primera consistia en una agrupacion de luz bastante intensa, pero menos que la de la luna al hallarse en los cuartos, y que se separaba del disco lunar unos cinco á seis minutos en la direccion de los dos diámetros N.E.—S.O. y N.O.—S.E., como si formase cuatro aspas irregulares en estas direcciones, mientras que hácia el N., S., E., y O., apenas se separaba unos dos minutos; el contorno general de esta parte luminosa era bastante irregular, tanto que, en algunos puntos, apenas se percibia; esta primera parte de la aureola parecia destacarse sobre una segunda agrupacion de lux, que se debilitaba á medida que se alejaba del cuerpo de la luna, y que por algunos lados se estendia hasta una distancia casi igual al diametro solar.

* In the coloured lithographic plate given in the "Anales del Observatorio de San Fernando" for 1871, from which the above woodcut has been made, the north-western and south-eastern sections of the corona are represented as hidden by cloud. The above woodcut has been oriented from the vertex. Assumed time of mid-totality $23^h\ 52^m\ 36^s$ local true time. Sun's axis 8° 7′ to the east of the vertex.

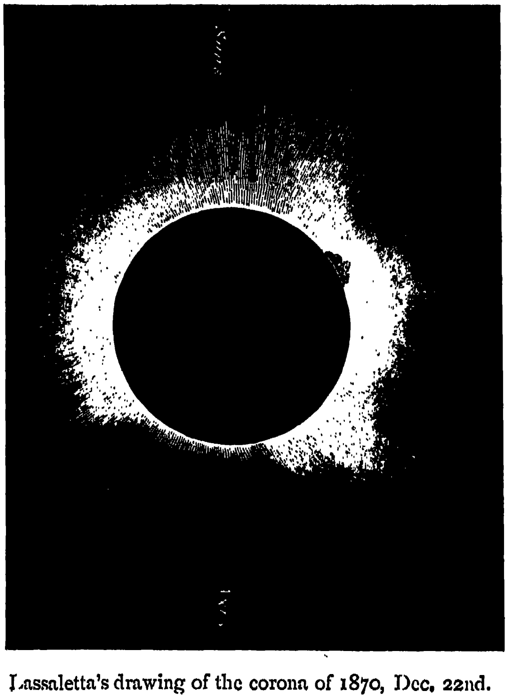
Lord Lindsay. 36° 38′ N. 6° 12′ W. MARIA LOUISA OBSERVATORY, Between San Lucar and Jeres, 22nd Dec., 1870.

[The five following drawings were brought home by Lord Lindsay, and are now bound up with the MSS. Reports of the 1870 Expedition. Don JOSE IGLESIUS, Don AURELIO LASSALETTA, Mr. A. THUILLIER, and Mr. EDWARD THUILLIER, all observed from Lord Lindsay's station, as also did Lieut. A. B. BROWNE, Mr. C. BECKER and Lieut. GREAVES. Mr. EDWARD THUILLIER, as well as Mr. C. BECKER, appears to have adopted the positions of the rays as measured by Lieut. GREAVES. The drawing by a Lady at Cadiz was also obtained by Lord Lindsay. It is delicately finished in coloured chalks.]



Drawing of the corona of 1870, Dec. 22nd, by a Lady at Cadiz.

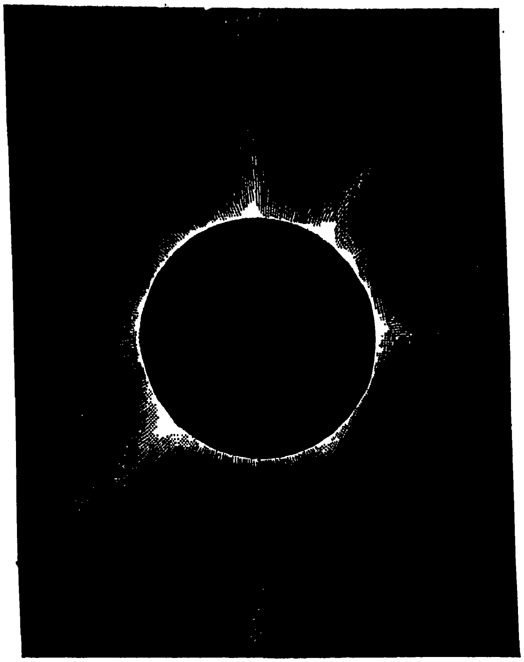
Drawings made at Lord Lindsay's station at Maria Louisa.



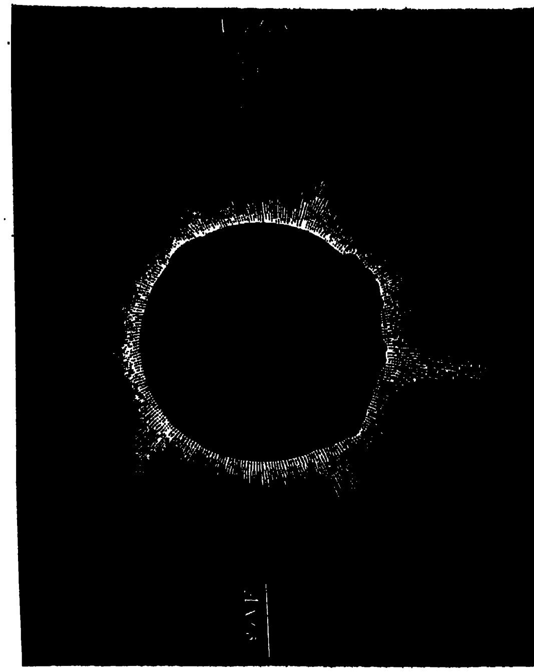
Lassaletta's drawing of the corona of 1870, Dec. 22nd.

A. Thuillier's drawing of the corona of 1870, Dec. 22nd.

Drawings made at Maria Louisa Observatory.

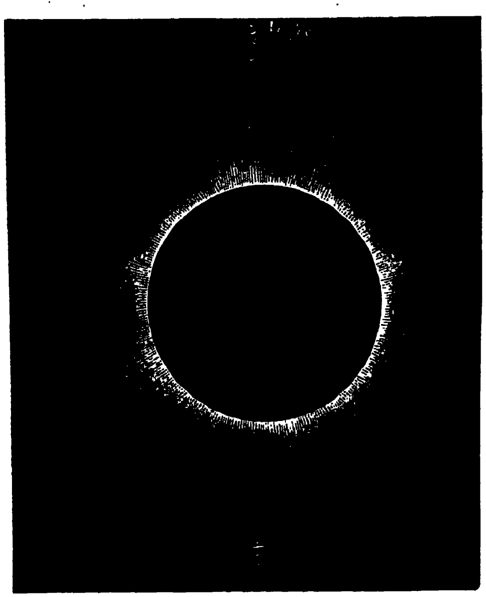


Ed. Thuillier's drawing of the corona of 1870, Dec. 22nd.



Iglesius' drawing of the corona of 1870, Dec. 22nd.*

Mr. C. Becker.



Becker's drawing of the corona of 1870, Dec. 22nd.†

36° 38′ N. } 6° 12′ W. } MARIA LOUISA OBSERVATORY, 22nd December, 1870.

MS. Reports of the 1870 Expedition.

Lieut. GREAVES, R.N., obtained the direction of the streamers by a position circle. In making my drawing I have adopted his measures. The black disc of the moon was surrounded by a band of silver light, and that encircled by a light violet-coloured corona extending in an irregular star-shaped figure from about 20′ to 40′ apparently from the moon's disc, and beyond this rays of light faintly coloured and shaded off by the passing clouds were noticed.

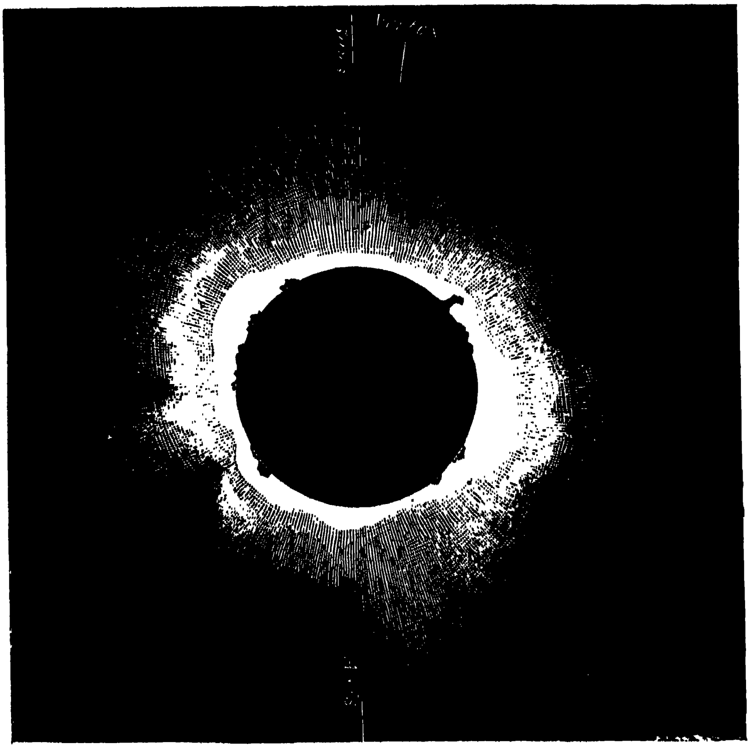
* All these drawings have been oriented from the vertex. Assumed time of mid-totality $23^h\ 52^m\ 36^s$ local true time. Sun's axis 8° 7′ to the east of the vertex.

† Made from a water-colour drawing accompanying Becker's MS. report. Oriented from

Lieut. Alex. B. Browne. 36° 38′ N. 6° 12′ W. MARIA LOUISA OBSERVATORY 22nd December, 1870.

"Monthly Notices," xxxi., p. 56.

(p. 55.) During totality I wished to see if my assistant at the finder was following my directions; and so requesting him to stand on one side for a few seconds, went myself to the finder, and saw the cross-wires on the part of the corona I wished to examine. For some ten or fifteen seconds I gazed at the dark orb surrounded by its glorious corona. [Here follows a description of the prominences.]



Browne's drawing of the corona of 1870, Dec. 22nd.*

(p. 56.) I have endeavoured to make a rough sketch of the picture presented to me in the telescope and by the eye; one remarkable part of which was the difference I noticed the corona to have near the sun; it seemed to me distinct from the rest of the corona, and to be irregular in outline, bulging out or extending much farther from the sun in some places, whereas in others it took the form of concentricity with the sun; it had, moreover, the colour and appearance of pearl, with a bright phosphorescent tone about it, and was similar and dense throughout,

the vertex. Assumed time of mid-totality $23^h\ 52^m\ 36^s$ local true time. Sun's axis 8° 7′ to the east of the vertex.

* Made from a water-colour drawing accompanying A. B. Browne's MS. report. Oriented from the vertex. Assumed time of mid-totality $23^h\ 52^m\ 36^s$ local true time. Sun's axis 8° 7′ to the east of the vertex.

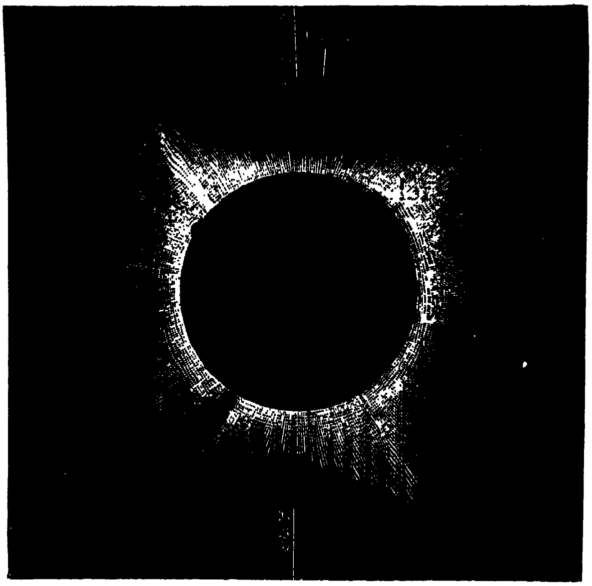
whereas the rest of the corona had a faint violet colour, tinged in places with faint green and faint yellowish-red, and decreasing in luminosity as its distance from the sun increased; moreover, it was jagged somewhat in outline, and had gaps in it (as seen in the sketch), and very faint striations* might be seen in it; the inner portion, as I have said, was quite different, and I should consider it an achromatic chromosphere surrounding the regular chromosphere, and separating it from the corona.

Mr. F. H. Browne.

36° 37′ N. } SAN ANTONIO, near Puerto de Santa Maria, SPAIN,
6° 11′ W. } 22nd December, 1870.

MS. Reports of the 1870 Expedition.

The corona appeared to me to be approximately quadrilateral; it extended farthest in the direction of the first point of contact. At an angle of 90° to this extension it appeared to be brightest; at an angle of somewhat more than 90° from this bright streamer there was a gap in the corona, to which I specially directed my attention. At about 45° from this gap the light from the corona first began to fade.



F. H. Browne's drawing of the corona of 1870, Dec. 22nd.†

No striation in corona.

The corona was of a pale white colour, and totally free from striations, the bright streamer having no visible striation. The outline of the corona was distinct. I could see it for three or four seconds after the end of totality.

* The striations have not been accurately followed in the woodcut, but the texture of the corona as shown in the drawing is not unlike that shown in the woodcut.

† Made from a carefully finished pencil drawing accompanying F. H. Browne's MS. report. Oriented from the vertex. Assumed time of mid-totality $23^h\ 52^m\ 40^s$ local true time. Sun's axis 8° 5′ to the east of the vertex.

Mr. Hostage. 36° 37′ N. 6° 11′ W. San Antonio, Spain, 23nd December, 1870.

MS. Reports of the 1870 Expedition.

The corona was not brilliant, but like pale moonlight, and of a silver white colour. I noted one dark streamer extending half a diameter of the sun's disc, in the direction shown in the sketch.

Hostage's drawing of the corona of 1870, Dec. 22nd.*

The corona extended from the sun's edge about a quarter diameter. It was almost concentric with the sun, but rather more extended to the eastern side.

[In a letter dated November 2nd, 1871, Mr. Hostage writes:]

* Made from a pencil sketch accompanying Hostage's MS. report. Oriented from the vertex. Assumed time of mid-totality $23^h\ 52^m\ 40^s$ local true time. Sun's axis 8° 5′ to the east of the vertex.

The telescope with which I observed the eclipse of the 22nd Dec., 1870, was the finder of the 8¾ in. Cassegrain. The diameter of the object-glass of the finder is 0·7 in., and its focal length 10 in. The magnifying power used was 4. The eyepiece gave a field wide enough to take in the whole corona and any probable streamers.

[In a letter dated the 20th of April, 1872, Mr. HOSTAGE, in answer to questions, writes :]

1st. The corona ended abruptly where the dark shading commences, in a form almost concentric with the dark image of the moon.

2nd. The corona's extent was about half the moon's diameter from the moon's edge.

3rd. The dark space beyond the corona was not absolutely black, the dark ray showing distinctly upon it. The dark ray just terminated within the field of the telescope—at a distance from the dark limb of about a solar diameter.

4th. My N. and S. points are meant for a perpendicular to the horizon of the place. The reason of their not being drawn vertical on the card, was that I had first marked down the positions of the red prominences, and dark ray, with reference to the wires in the telescope, and I afterwards referred the position of the wires to the horizon. From memory, I should incline to think that if there is any mistake, the N. and S. points should form a greater angle with the dark ray, but I would rather trust to the sketch I made at the time.

Mr. W. H. H. Hudson.

36° 37′ N. } 6° 11′ W. } SAN ANTONIO, SPAIN, 22nd December, 1870.

MS. Reports of the 1870 Expedition.

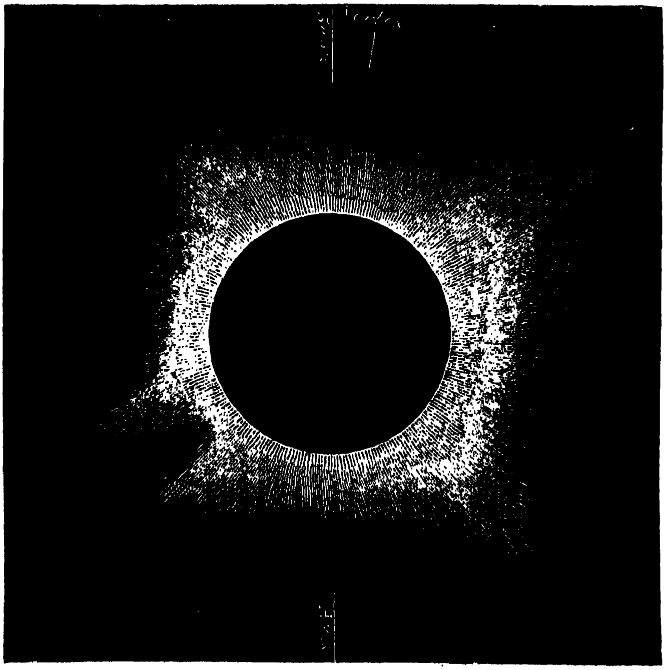
Time was nearly up ; I took my eye from the telescope, and for a few seconds saw the general appearance of the corona and prominences. I distinctly noticed the quadrilateral shape of the corona, and that the sides of the quadrilateral were roughly horizontal and vertical. The greatest extension was to the north-west, and was about three-quarters of the moon's diameter.

I saw the corona about three-quarters of a minute longer than the totality. Immediately after totality I hastily made a sketch of the im-

pression, scarcely gone from my eye, of what I saw without the telescope. This was very rudely and almost automatically done, but agrees very closely with Mr. F. H. BROWNE's sketch.

Mr. BROWNE was standing by my side to make the sketch; he did not see mine, nor I his, till both were completed.

I append to this report a rude chalk drawing made since my return from Spain. It represents the corona only, and is taken from my sketch and from memory.



Hudson's drawing of the corona of 1870, Dec. 22nd.*

The Rev. S. J. Perry.

36° 37′ 13″ N.
6° 11′ 13″ W. SAN ANTONIO, SPAIN, 22nd December, 1870.

MS. Reports of the 1870 Expedition.

The effect to the naked eye was destroyed by the intervening cirrus clouds.

There was a narrow rim of light of a pale white around the limb, equal in breadth to one-fifth of the lunar radius; and this rim, as seen through the clouds, was certainly not more than one-eighth of the brilliancy of the moon's surface on a cloudless night. Receding from the limb, the light faded off, at first gradually, and then rapidly; it could be traced to the distance of about seven-eighths of the moon's diameter.

The outline of the corona was of a quadrilateral form, not well defined;

* Made from the drawing in chalks accompanying Mr. Hudson's MS. report Oriented. from the vertex. Assumed time of mid-totality $23^h\ 52^m\ 40^s$ local true time. Sun's axis 8° 5′ to the east of the vertex.

and I noticed four parts of the corona where the light was less strong than in the rest, these being more or less equally distributed round the moon. A fifth dark part was less well marked; they all appeared to be radial.

I did not lose sight of the corona for thirty-five seconds after totality.

Prof. S. P. Langley. 36° 43′ 56″ N. 6° 10′ 8″ W. JEREZ, 22nd Dec., 1870.

"Nature," Vol. iii., pp. 228, 229.

I employed a good achromatic, of four inches aperture, with a power of about 150, in the direct study of the coronal structure, with negative results. On the closest scrutiny of the part nearest the sun, nothing was seen but a nearly uniform diffuse light, except that one "dark ray" in the field was noticed to be absolutely straight and nearly radial.

The outline of the corona was roughly quadrangular; and a heavy field bar provided for the purpose being carefully set during totality in the direction of the longer diagonal, was found on subsequent estimation to make an angle of as nearly as possible 45° with the vertical. . . .

If I compare my impressions with those of others, or even with my own of last year, I find difference enough to suggest the probability of considerable "personality" in all such statements. In some well-marked features all agree, in other minor ones such difference exists that one might almost say each saw a different corona.

Mr. Naftel 36° 43′ N. 6° 10′ W. JEREZ, SPAIN, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

[Drawing hanging in the Council Room of the Royal Astronomical Society.]

The corona was radiating, and not perfectly circular, and varied as totality progressed; it was never symmetrical, and much too vague to enable me to describe by a line, excepting where a curved opening on the left-hand lower limb of the moon occurred, as shown in the drawing. The colour of the corona was warm white, and I could perceive nothing approaching a defined edge to the bright light immediately round the

moon; it simply became less bright as the distance increased from the moon, though the contrast of the dark moon with the brightest part of the corona might indüce a less practised observer to call it a ring of

Naftel's drawing of the corona of 1870, Dec. 22nd.*

light. The drawing I send with this was painted immediately after, and is as true in colour and general effect as anything I ever did.

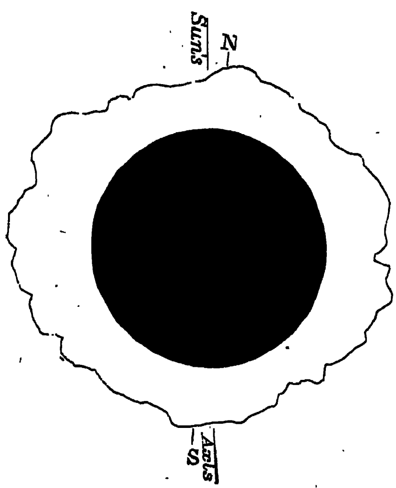
Mr. Norman.	36° 43′ 56″ N. } 6° 10′ 8″ W. }	JEREZ DE LA FRONTERA, 22nd Dec., 1870.

"United States Coast Survey Report" for 1870, Appendix No. 16.

(p. 35.) [Prof. YOUNG says:] In accordance with an idea I had formed some time ago, I made arrangements to secure a tracing of the corona,

* The above woodcut was made from a water-colour drawing, now in the possession of the Royal Astronomical Society. It has been oriented from the vertex. Assumed time of mid-totality $23^h\ 52^m\ 48^s$ local true time. Sun's axis 8° 19′ to the east of the vertex.

hoping to ascertain whether there is any difference between the visible corona and the same thing as depicted in photography. For this purpose a comet-seeker of 95 millimeters aperture, and 760 millimeters focal length, was employed. A diagonal eyepiece of low power was used, forming an image of the sun about 17 millimeters in diameter upon a plate of glass very slightly roughened by grinding with the finest emery—just enough to give a hold to the point of a pencil. This image of the sun, seen by transmitted light of course, was very bright and sharp, and I was in hopes that that of the corona would be so likewise.



Norman's tracing of the corona of 1870, Dec. 22nd.*

Mr. Norman, an English gentleman resident in Jerez, and an artist of no inconsiderable skill, kindly undertook the instrument, and during the totality made one tracing and commenced another, which are interesting when compared with the photographs. He found, however, that the ground glass too much diminished the light, and he could not see on the plate many of the details (especially the dark rays) which were conspicuous to the naked eye. The drifting clouds greatly increased the difficulty.

If the experiment were to be repeated, I should propose that the tracing be made with a needle point upon a plate of gelatine or mica. Annexed is a copy of Mr. Norman's tracing.

Prof. C. A. Young. 36° 43′ 56″ N. } 6° 10′ 8″ W. } Jerez de la Frontera, 22nd Dec., 1870.

"United States Coast Survey Report" for 1870, Appendix No. 16.

(p. 31.) I determined now to take one deliberate look at the eclipse, and did so for about ten seconds. What I saw certainly appeared to me very different from the impressions of the eclipse of 1869. Then, under an absolutely clear sky, the corona seemed to me somewhat smaller and

* Made from an outline woodcut, given in the "United States Coast Survey Report." North pole of sun's axis 6° 44′ to the east of the north point.

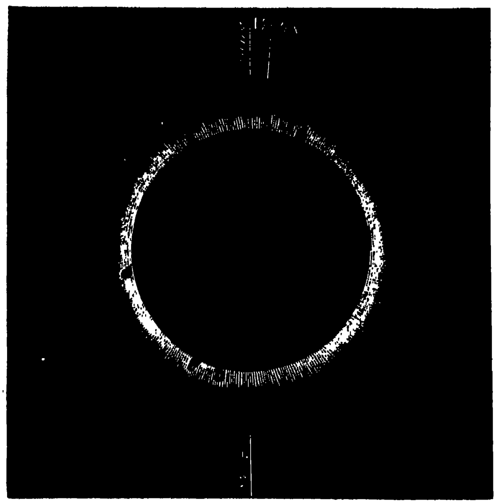
more sharply defined than now; far more brilliant and more beautiful then, but striated only with fine lines without heavy markings. (Some of the observers, however, who were in Kentucky in 1869, made a very different comparison of the two eclipses.) On this occasion the corona appeared very indefinite in its outline; roughly square with its diagonals at an angle of about 45° with the vertical, (and with the ecliptic also, since the eclipse took place at noon, and the sun was near the solstice,) and having the sun somewhat out of the centre.

But I was most struck by several straight dark streaks apparently related to the protuberances, which extended out from the sun through the corona and into the sky beyond, to a distance fully equal to the sun's diameter.

Mr. Abbatt. 36° 8′ N. } 5° 21 W. } GIBRALTAR, SPAIN, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

The weather during the day was very unfavourable, heavy clouds driving across the Bay from the west almost continually, so that I had scarcely ever occasion to use a coloured glass.



Abbatt's drawing of the corona of 1870, Dec. 22nd.*

I used a power of 40 on my telescope, and watched the progress of the eclipse till the thinnest streak of the sun vanished, and I saw nothing. In about a second, and as if instantaneously, the corona and the red prominences were in view; how they got there I cannot tell, as my eye was on the moon all the time. The prominences extended, I think, farther from the moon than the light of the corona, unless it shaded off. The corona was not of equal width all round. I thought its light more intense next the moon's limb.

* Made from a sketch accompanying Abbatt's MS. report. Oriented from the vertex. Assumed time of totality $23^h\ 29^m$ local true time. Sun's axis 7° to the east of the vertex.

Prof. Simon Newcomb. $36^\circ\ 6'\ 43''$ N. $5^\circ\ 20'\ 51''$ W. BUENA VISTA, NEAR GIBRALTAR, 22nd Dec., 1870.

"Washington Observations" for 1869, Appendix I.

(p. 10.) A comet-seeker of 32 inches focus and 4 inches aperture was made use of, and a power of 40 was selected for the observation of the eclipse.

(p. 11.) As soon as I had recorded the time of disappearance I put my eye again to the telescope. Instead of the gorgeous spectacle I witnessed in 1869, I saw only the most insignificant corona, although the full aperture of the telescope was used. Supposing that this was of course due to the clouds, I kept my eye at the telescope in hopes of their disappearance, still, however, scrutinizing the phenomena most carefully. I could not see the slightest trace of bright or dark points, rays or filaments, the light everywhere seeming as soft and diffused as the zodiacal light.

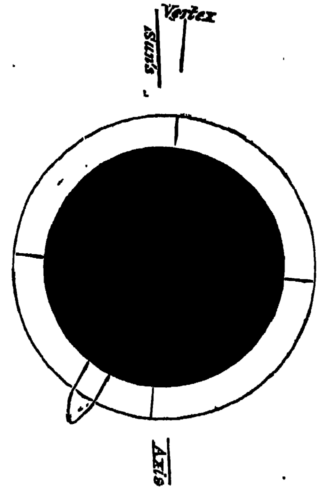
There were indeed, as in former eclipses, great differences between the extent and brilliancy of the corona at different points, but all the parts seemed to shade into each other by insensible gradations. . . . .

I waited in vain through the few moments of total eclipse for the corona to be seen more distinctly, and observed the reappearance of sunlight under the impression that the clouds had prevented me from seeing more than a very little of the corona. But after finishing my observations, Mr. SPRAGUE and Mr. NEWCOMB, both of whom were outside my tent, agreed in testifying that the sky in the direction of the sun seemed quite free from clouds during the entire total phase, and that two stars were distinctly visible in the neighbourhood of the sun. It is a little singular that while the two parties agree in describing the positions of the stars, their descriptions are not reconcilable with the positions of Venus or Saturn, the only bright planets in the neighbourhood of the sun. I bring this forward as tending to excite suspicion that the corona is subject to very great changes of brilliancy—a suspicion, however, which can be removed or confirmed only by the observations of others. My own testimony is simply this: the corona of 1869, through a haze which rendered all but the brightest stars invisible to the naked eye, seemed to me many times more brilliant than that of 1870, seen through an atmosphere which permitted at least the brighter planets to be seen.

Mr. J. H. Anson. 36° 25′ N. } 5° 10′ W. } ESTEPONA, SPAIN, 22nd December, 1870.

MS. Reports of the 1870 Expedition.

Just after the beginning of totality there was a break in the clouds, and I was able to see the corona. It was not, however, visible for ten seconds, so that my impressions were of necessity not very certain. I saw a ring of light, white or nearly so, round the moon's disc, which appeared to increase in size, and when I last saw it, its breadth was about one-fourth of the moon's radius. I saw also a streamer (if I am right in calling it one) in the south-west quadrant, at about 35° from the vertical; it did not appear to be radial, but to tend towards the vertical at its outside extremity. It projected about half a moon's radius from the edge of the moon's disc. Its colour was crimson.



Anson's drawing of the corona of 1870, December 22nd.*

Mr. Gillman. 41° 10′ N. } 2° 17′ W. } ARGOS, SPAIN, 22nd December, 1870.

MS. Reports of the 1870 Expedition.

Argos is about 900 feet above the sea level. As totality came on I laid aside all apparatus and observed with the naked eye. What I saw I have represented as faithfully as I could in three sketches, of which the accompanying are copies.

No. 1 shows the corona as it appeared to me immediately upon the commencement of totality; and although the large prominence on what may be called the S.E. of the disc was very distinct, I failed to observe any prominence on the N.E.; nevertheless, the angular appearance of the corona to the N.E. was almost as well developed as to the S.E.

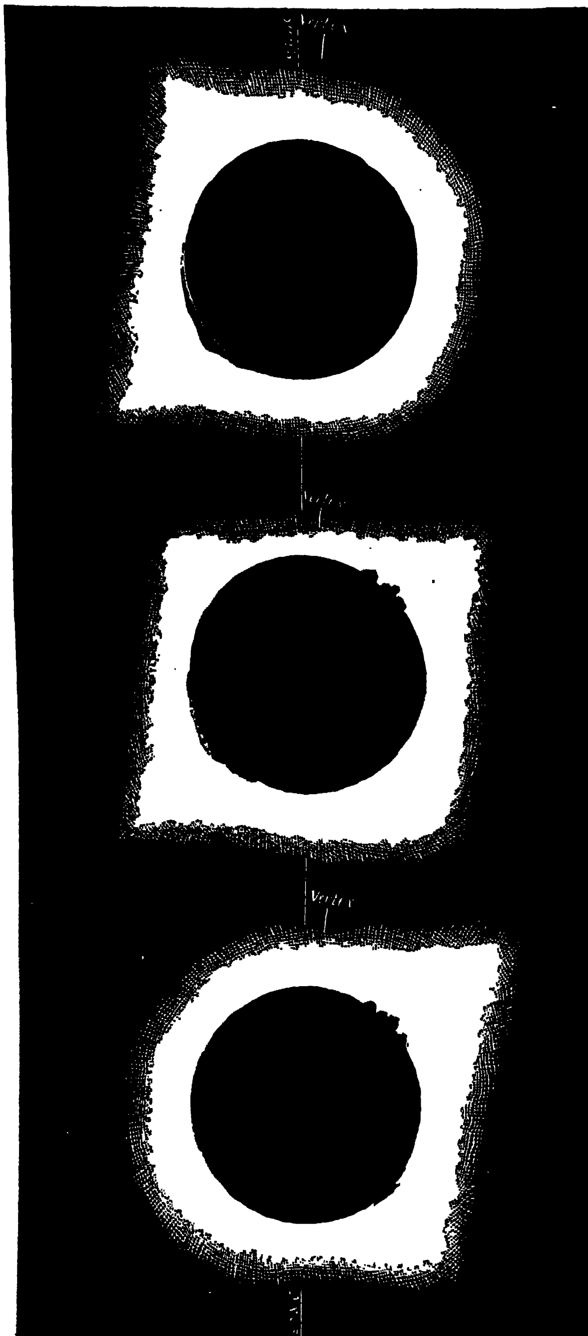
The aspect of the whole assumed the form of a D, remaining unchanged, as far as I was able to judge, for twenty seconds, when three

* Made from a sketch accompanying Anson's MS. report. Oriented from the vertex. Assumed time of mid-totality $23^{h}\ 59^{m}\ 12^{s}$ local true time. Sun's axis 6° 55′ to the east of the vertex.

Fig. No. 1.

Fig. No. 2.

Fig. No. 3.



Gillman's drawings, showing the corona of 1870, December 22nd, as it appeared to him—(1) Immediately after the commencement of totality; (2) Towards the middle of totality; (3) Just before the end of totality.*

fine prominences shot out distinctly on the N.W. of the disc, and at the same instant the corona became quadrilateral. (Fig. No. 2.)

It appeared distinctly canted, and the S.E. and N.W. corners were brighter and more prominent than the S.W. and N.E. corners, which extended only one-third of the moon's diameter, whilst the projection of the former was equal to the radius of the disc. The width of the corona on the four sides was equal to half the moon's radius.

A dense cloud then sailed across the moon, and obscured it from my view for several seconds; when this obstacle had blown over, I no longer saw the bold prominence on the S.E. The S.E. and N.E. corners of the quadrilateral had also disappeared.

The three N.W. prominences were if anything more vivid than before, and the whole looked like an inverted D. (Fig. No. 3.)

The boundary of the

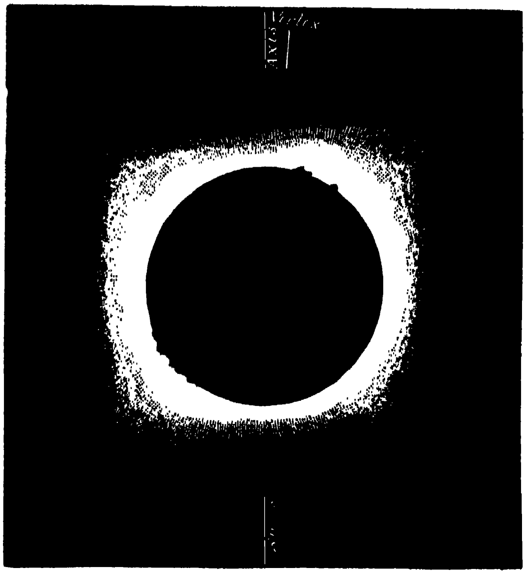
* Made from water-colour drawings accompanying Gillman's MS. report. Oriented from

corona was defined, though somewhat hazy and with slight coruscations. The corona itself appeared to me more as a luminous haze than anything else, although I observed faint signs of light—too indistinct, however, to make note of. The intensity of the corona's light appeared greater within a narrow zone, concentric with the moon, and about one-fourth the moon's radius in width. The light was also very intense in the neighbourhood of and in front of the prominences. The state of the atmosphere was a great obstacle against any appreciation of the darkness of the moon's disc, as compared with that of the sky.

Mr. Warrington Smyth. 41° 10′ N. } ARGOS, SPAIN,
2° 17′ W. } 22nd December, 1870.

MS. Reports of the 1870 Expedition.

The town of Argos is situate about twenty miles E. by N. from Jerez and about ten miles north of the central line.



Warrington Smyth's drawing of the corona of 1870, December 22nd.*

We took up our position on the top of the tower of the church of Santa Maria, where the vicario kindly gave us sole possession. The elevation of our post was estimated by Mr. M'Pherson barometrically at 850 feet.

Through a telescope, 20-power and $2\frac{1}{8}$ aperture, I was able to see the last thread-like crescent of the sun disappear; but immediately after some bright prominences had shone out in the south left-hand quadrant of the sun, and a narrow band of corona appeared, a small thick cloud came up, and a vulture which, with seven others, had been soaring overhead, sailed

the vertex. Assumed time of mid-totality $0^h\ 18^m\ 36^s$ local true time. Sun's axis 2° 23′ to the east of the vertex.

* Made from a water-colour drawing accompanying Warrington Smyth's MS. report. Oriented from the vertex. Assumed time of mid-totality $0^h\ 18^m\ 36^s$ local true time. Sun's axis 2° 23′ to the east of the vertex.

across the field at the same moment, and I saw nothing more for about half a minute. Then the disc of the moon, black to my own and companion's view, and certainly much darker than the background of sky, appeared again in a clearer gap. The corona, much less vivid than I had seen it from Bruges in 1860 (more than 2,000 feet above the sea level), was for the most part one-fourth of the diameter of the moon in width, but assuming a roughly quadrilateral figure, one of the angles being opposite the above-mentioned prominences, and another chiefly noticeable angle in the prolongation of a diameter from the same point. In these the extreme length of the brightness was a semi-diameter, but the boundary was not very definite.

Corona not so vivid as in 1860.

I saw no change in the corona beyond what was caused by the varying thickness of drifting cloud, except only a greater brilliancy at the right-hand upper quadrant, towards the end of the totality.

The general tint of the corona was a silvery whiteness, without any unequal distribution of colour.

Prof. A. Tacchini. 37° 3′ 56·2″ N. 14° 14′ 15″ E. TERRANOVA, 22nd December, 1870.

"Rapporti della Commissione Italiana," p. 129.

Tutto attorno alla corona e fascia luminosa sovrastava una bellissima aureola di una luce assai meno intensa e di un color biancastro argenteo, dell' altezza di poco più di un raggio lunare, il cui limite era ben determinato sebbene non continuo, ma leggermente frastagliato. La suddetta aureola non appariva formata di una luce omogenea, uniformenente sfumata, ma risultava come composta di tanti raggi sottilissimi assieme riuniti e normali al bordo lunare.

The corona did not appear to be formed of a homogeneous light, but was made up of a number of fine rays, some in groups and normal to the moon's limb.

L' aureola che immediatamente seguiva la corona, essa pure concentrica al disco lunare, era di tratto in tratto interrotta da vivissimi fasci di luce, che spiccavano distintissimi sulla tinta più pallida dell' aureola stessa e sul fondo oscuro del cielo. La lunghezza di questi fasci di luce *o pennacchi* era prossimamente di un diametro lunare o poco più. . . . . Una particolarità relativa ai pennacchi che immediatamente mi colpì si fu la loro forma singolare, cioè stretti alla base poi divergenti fino a due terzi dell' altezza loro, e poscia acuminati alla parte superiore, con questa particolarità, che quasi tutti ed i più belli

Synclinal groups.

avevano da una parte il limite rettilineo dalla base alla sommità, il quale limite rettilineo aveva la massima intensità di luce, come meglio si può scorgere e comprendere dall' ispezione semplice della figura della tavola II.*

A preferenza degli altri distinguevasi nella parte superiore del disco lunare un magnifico pennacchio, che presentava prossimamente la forma di una losanga molto allungata, e di una larghezza assai maggiore e più vivace nelle parte mediana, mentre negli altri, come accennai, la parte più luminosa corrispondeva al tratto o limite laterale rettilineo.

Group near the vertex in the form of an elongated lozenge.

La lunghezza approssimata dei pennacchi era compresa fra due e tre semidiametri lunari. Come l'ultimo lembo del sole fu coperto dalla luna, corona e pennacchi comparvero di un tratto e direi quasi non come fenomeno che si formava in quell' istante, ma come cosa gia esistente e preparata che si scopriva all' istante della totalità. I pennacchi si conservarono sempre della stessa larghezza, lunghezza e forma, intensità luminosa e posizione relativa durante l' intiero tempo della totalità.

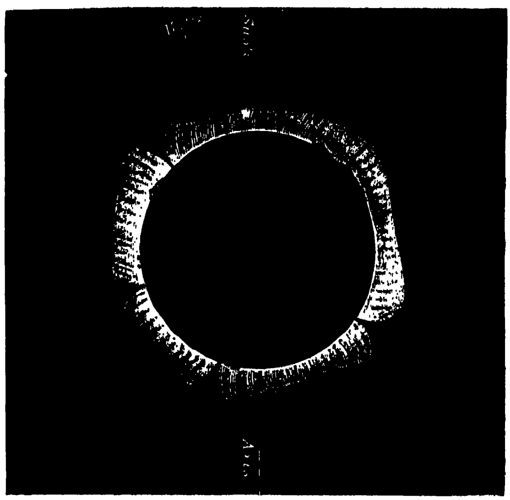
No change in groups of coronal structure during totality.

Prof. J. C. Watson.

37° 14′ N. } CARLENTINI, SICILY,
15° 1′ E. } 22nd December, 1870.

"U.S. Coast Survey Report" for 1870, Appendix 16, pp. 17-18.

A few minutes before the totality began, the cloud broke and gave us perfectly clear sky in the neighbourhood of the sun. . . . As soon as the last rays of the photosphere disappeared, I immediately sketched, with the naked eye, the outline of the bright corona, and having completed its trace I compared the sketch with the sun, in



Watson's drawing of the corona of 1870, December 22nd.†

* Tacchini's drawing appears to be a mere diagram intended to represent the general appearance of the corona.

† The above woodcut was made from a lithographic plate published in the "U.S. Coast Survey Report." Oriented from the vertex. Assumed time of mid-totality $2^h\ 1^m$ local true time. Sun's axis 19° 10′ to the west of the vertex.

order to be assured of its accuracy. Then, without loss of time, I placed my eye at the telescope, already adjusted for sharp definition. In the first place I moved the telescope around the limb of the moon to see whether the outline and extent of the corona agreed with the sketch already made; and having assured myself of this fact, I then sketched the places of the principal prominences as reference points for the positions of remarkable indentations in the corona which were conspicuous in passing round it. Having sketched the places and the form of these indentations, I then studied carefully, for a few moments, its structure, and sought to notice particularly whether any changes whatever took place. As soon as I saw that the totality was about to end, I again traced the outline of the corona as visible to the naked eye, and the total phase, lasting one hundred and ten seconds, had passed. Fully sensible of the impossibility of sketching more than outlines during the short period of totality, I did not attempt more, and I was thus enabled to devote attention to details of structure and to other phenomena which would otherwise have passed unnoticed. The sketches were made in my note-book with pencil, but as soon as the totality had passed I sat down and wrote out full explanations of the meaning of the marks made, as well as full descriptions of the phenomena which I observed. Upon returning to Catania, I spent the greater portion of the next three days in making, from these sketches—while everything connected with the appearance of the corona was vivid in my mind, and before I could be influenced in my judgment by any reports of what was seen by others—two crayon drawings,* which I send you with this report, the first showing the corona as it appeared to the naked eye, the other showing it as it appeared in the telescope. . . . .

From the beginning to the end of the total phase the bright solar corona, so far as I could see, was absolutely constant both in form and brilliancy; but I noticed that the exterior or faint corona was first brighter and more extensive on the eastern limb at the beginning of totality, and then perceptibly brighter on the western side as the

* Only the second of these drawings, showing the corona as it appeared in the telescope, has been copied; they are nearly identical in their general outline, but in the naked-eye view the rifts do not extend down to the moon's limb, and the inner corona is structureless.

total eclipse ended. . . . . The positions of these cusps, measured from the vertex of the sun towards the east, were approximately as follows: First cusp, 26°; second cusp, 93°; third cusp, 142°; fourth cusp, 220°. These angles, it must be understood, are not the results of exact measurements, but simply the mean of the results obtained by estimation from two independent sketches of their relative positions. Their position in reference to neighbouring prominences is correctly shown on the drawings, and when the exact places of these prominences shall have been determined, we may thus derive more exact values. The first three of these cusps were more distinct as seen in the telescope than the fourth, but not quite so large.

An examination of the coronal parts between these apparent indentations, which I have called cusps, showed that for a distance of perhaps 1′ from the limb it was of intense uniform brilliancy, then passing outward were streams of luminous matter, extending to near the outer extremity of the corona, where they were again blended together into a bright even band, which marked the limit of what appeared to be the real solar corona. These radiating streams were separated by more faintly illuminated interstices, and thus gave indications at some points of an apparent radial structure of the corona. In the vicinity of the cusps these lines were curved conformably to the cusp, the curvature becoming less and less receding from the cusp until, at a point midway between two cusps, the lines or streams were radial. This structural form was most distinct on the eastern limb, and in the immediate vicinity of the cusps.

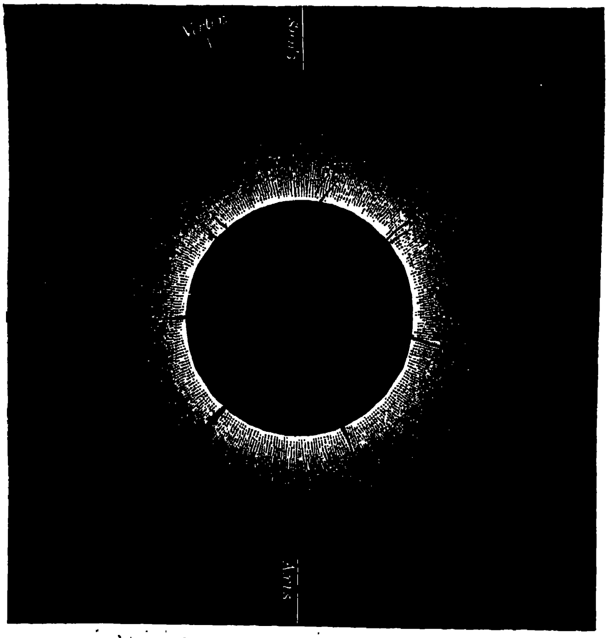
(p. 19.) The drawing gives the telescopic view of the corona. The positions and the form of the cusps are correctly indicated. The streams of light already mentioned are also shown; but I did not succeed, with the crayons which I had at hand, in giving precisely the correct delineation. The form of these streams and their relation to the cusps are indeed clearly indicated, but there was a general effect which, having failed to indicate sufficiently in the drawing, I will attempt to describe.

The appearance in the telescope reminded me of the great comet of 1858, which I observed attentively. There was in the corona first a uniform band of light, pearl-white, as in the case of the bright comets. Then streams of luminous matter flowing out, and afterwards spreading

and uniting, thus forming a shell-like envelope to the sun. It seemed as if the cusps were merely rents in this envelope, and as if I were looking into a partially transparent shell, within which was a brilliant core emitting luminous streams. The manner in which the exterior halo enveloped the solar corona is not exactly shown in my drawing. The cusps were dark at the apex, and quite bright at the extremity of the corona, but not nearly so bright as the other portions of the corona; so that, being of a brilliancy not much in excess of that of the outer halo, the appearance was that of the formation by the latter of a sort of envelope passing down into the indentations of the former.

Mrs. Charles S. Peirce. 37° 30′ N. 15° 5′ E. VILLA SAN GIULIANO, near CATANIA, 22nd December, 1870.

"U.S. Coast Survey Report" for 1870, Appendix 16, pp. 12, 13.



Mrs. Peirce's drawing of the corona of 1870, Dec. 22nd.*

[During the few days preceding the eclipse, Mrs. Peirce practised herself in copying a picture of the corona made at a former eclipse by Padre SECCHI, and in sketching over and over again as rapidly as possible the outline of the ever-changing steam-cloud that rolled continually out of Etna.]

I began to draw, and even as I had practised from my pictured corona, I began at the lower side of the left-hand upper quarter and passed round through the right-hand upper quarter. But I

* The above woodcut was made from a coloured lithographic plate given in the "U. S. Survey Report." Oriented from the vertex. Assumed time of mid-totality $2^h\ 3^m\ 18^s$ local true time. Sun's axis 19° 23′ to the west of the vertex.

could see no bright rays such as I had been copying—only a radiation of dark lines over the bright halo, a few of which I put down as seen in my drawing, just to show the character of them, not as portraits of individual lines. Indeed, I said to myself that it was of no use to try to draw them, because there was, or I thought there was, a cloud over the corona comprising them. I soon turned my eyes and my pencil, therefore, to the lower left-hand quarter. What was my astonishment to find here, not a long and broad bright ray, wide at the base and narrowing to a point, as in SECCHI's corona, but a long dark, or rather delicate grey or steel-coloured ray, narrowest at the sun and widening as it went out, which entirely crossed the bright halo, and ceased or lost itself only on the very outside edges of the hazy envelope beyond. I put it in its place exactly as it appears in the drawing, and going farther round the diameter, found a more delicate and shorter one about half-way between the two lower quarters, and, farther on still, a still shorter one in the upper part of the right-hand lower quarter; and then the eclipse was over, and I had had no time to verify my observation on the lower half, or to scan once more the upper half, in order to see whether there were not some dark rays there which I might have overlooked.

So very delicate was the tint of these rays, so lost in the general halo, and so short was the time, that I doubt, had I not happened to have my attention fixed on the idea of rays alone, whether I should have discovered them at all.

Prof. J. Homer Lane. 37° 30′ 13·4″ N. } 15° 5′ 23″ E. } CATANIA, 22nd Dec., 1870.

"U.S. Coast Survey Report" for 1870, Appendix 16, p. 5.

A rent in the cloud revealed the eastern and northern parts of the corona (about 120° of the lunar circumference) for about three seconds.

This part of the corona had a sharp outline nearly concentric with the moon, except on the north-east, where it extended to a greater distance; its average width was estimated at one-third of the moon's radius.

There was no gradual shading off, and no long rays, as were noticed at Springfield, Illinois, during the total eclipse of August 7th, 1869.

Mr. Burton. 37° 14′ N. } 15° 13′ E. } AGOSTA, SICILY, 22nd December, 1870.

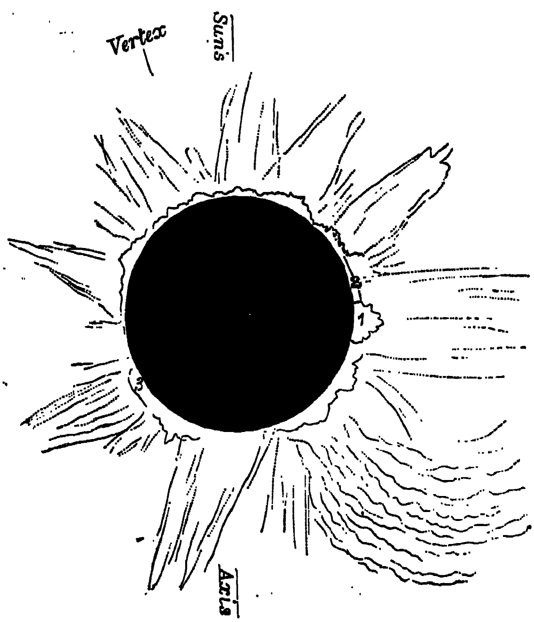
MS. Reports of the 1870 Expedition.

I looked for the place of the sun with my undefended eye—the eye not used for spectroscope work. The western half of the corona was unveiled, and in this momentary glimpse I saw no rays, but its colour was silvery white, fading gradually in brilliancy outwards. I am not certain whether the outer boundary was definite or not, but I incline to the latter opinion.

Its breadth was about two-thirds the diameter of the moon.

Corona very irregular, and always brighter above the protuberances. The iridescent region of the clouds is also shown in the drawing

Padre Corallo. 37° 14′ 20″ N. } 15° 13′ E. } AUGUSTA, 22nd Dec., 1870.



Corallo's drawing of the corona of 1870, Dec. 22nd.*

"Rapporti dalla Commissione Italiana," p. 23.

Il Signor ARCIPRETE di Augusta Can. Corallo fece un disegno della corona, che credo utile di qui soggiungere. . . .

Nel disegno è tracciata la ricomparsa della fase lucida pel Sole, è notato che la corona è molto irregolare, e sembra più lucida sopra le protuberanze! Vi è indicata pure la regione iridata delle nubi Mons. CORALLO usò un binoculo di ottima condizione, nel fare questo disegno.

Mr. Ranyard. NEAR VILLASMUNDA, SICILY, 22nd Dec., 1870.

MS. Reports of the 1870 Expedition.

[The corona was observed through a telescope with a biquartz in its

* Made from a lithographic plate given at the end of the "Rapporti dalla Commissione Italiana." Oriented from the vertex. Assumed time of mid-totality $2^h\ 4^m\ 24^s$ local true time. Sun's axis 19° 45′ to the west of the vertex. In the lithographic drawing the words *rossastro sfumato* and *verde sfumato* are written upon the curving structure in the south-west region of the corona.

principal focus and a Nicol's prism packed amongst the lenses of an erecting eyepiece, an arrangement by which a great deal of light would be lost.] My attention was taken by a red ray with sharply defined edges, in the lower left-hand quadrant. At first the idea passed through my mind that it must be caused by a flaw or small cross crystal in the biquartz; but I had observed none before, and it shifted with the corona as I moved the telescope. I felt very uneasy, as if I were observing something which ought not to be there; but nevertheless made a note of the ray, drawing at the time two lines in my note-book to represent the edges. [The woodcut on p. 315 represents the position of the ray as drawn in the note-book, and corresponds to the unoriented * image of the corona.] The two lines were very hurriedly drawn, and I am not sure that their inclination and position even approximately represent the inclination and position of the edges of the ray.

Prof. Asaph Hall. 37° 3′ 53″ N. } SYRACUSE,
15° 18′ 57″ E. } 22nd Dec., 1870.

"Washington Observations" for 1869, Appendix 1, pp. 28, 29.

(p. 27.) My telescope was a comet-seeker by Ploessl, with a 3⅞-inch object-glass and a magnifying power of about 50. . . .

(p. 28.) My chief purpose during the eclipse was to observe the structure of the corona, with special reference to the curved and radiating lines seen in previous eclipses; but the condition of the sky was such that this observation was unsatisfactory. After recording my observed time of the beginning of total eclipse, I pointed the telescope to the east limb of the moon and swept around toward the south back to the starting-point. I should not estimate the extent of the corona to be more than 5′ or 10′ from the limb of the moon, but the clouds make this estimate quite uncertain; and with regard to the form or outline of the corona, it could not, I think, be observed with accuracy.

The appearance of the corona in the telescope was that of a soft, white, diffused light; there was very little appearance of the radiating lines shown in many pictures, and I saw no curved streamers.

* As seen from Villasmunda the north pole of the sun's axis was about 20° to the left of the vertex.

Near the south-western point of the moon there was apparently a deep opening in the corona, reaching nearly to the limb of the moon, but on account of the clouds this opening was very indistinct. . . . . .

Having some fifteen or twenty seconds to spare, I looked at the eclipse with the naked eye. The moon was still covered with the light and shifting clouds, but as they were rising and passing towards the east the lower and south-western part of the moon was much the clearer. At this point the corona was quite bright, and here several delicate streamers shot down to the distance of eight or ten degrees.

Prof. Wm. Harkness. 37° 3′ 53″ N. } 15° 18′ 57″ E. } SYRACUSE, 22nd Dec., 1870.

"Washington Observations" for 1869, Appendix 1, pp. 45*—81.

(p. 80.) I observed the commencement of totality with my naked eye. The cloud was sufficiently transparent to allow the corona to be seen through it, but of course much diminished both in extent and brilliancy; and I do not think it was more than half or two-thirds as extensive as that which I witnessed at Des Moines in August 1869. On that occasion it had a well-marked trapezoidal form, but this time it seemed to me to be nearly circular; however, my view of it was limited to a mere glance at the commencement of totality.

Capt. Tupman. 37° 3′ 53″ N. } 15° 18′ 57″ E. } SYRACUSE, 22nd Dec., 1870.

"Washington Observations" for 1869, Appendix 1, p. 117.

The first part of the corona that attracted my attention was a ray or enlargement in the right upper quadrant, a little to the right of the very bright protuberance; but by the time that Prof. HARKNESS had done with the polariscope, which could hardly have been ten seconds, the left and lower left parts were the largest and brightest, and so they remained until near the end of totality, when the part in the right lower quadrant almost if not quite rivalled them. The latter ray did not enlarge suddenly, but very gradually indeed. The upper part of the corona was throughout the faintest. The extreme right was also faint until quite at the end of totality, when it brightened a little. No part increased in brilliancy without ex-

tending itself farther from the moon at the same time, so as to become a more or less pointed ray. I do not think any part of the corona extended farther than 25′ from the limb of the moon; no part was less than 10′, if so little.

Of the structure of the corona I have the liveliest recollection. It was made up entirely of the fine black lines (that is, black enough to be distinctly visible on a white background), which commenced imperceptibly at a short distance from the chromosphere, and went off into the sky beyond. They were continuous and uniform, but unequally distinct and unequally distributed, although close together everywhere. There were no curved or crossed lines, or lines radiating from any other point. [A coloured lithographic plate is given from a drawing by Capt. Tupman, in which the corona is represented as extending to the greatest distance from the sun's limb in the north-east and south-east quadrants.]

Prof. Eastman. 37° 3′ 53″ N. } 15° 18′ 57″ E. } SYRACUSE, 22nd Dec., 1870.

"Washington Observations" for 1869, Appendix 1, p. 127.

The structure of the corona appeared essentially the same as in 1869, and consisted of three distinct portions.

That portion next the edge of the moon, in many cases nearly obscured by the low and quite continuous range of protuberances which stretched along the limb of the sun for about 150°, was nearly white, and resembled the denser portions of nebulæ. It seemed to be concentric with the sun, and I estimated its height, at the point near the large protuberance, at about 1′. The height of the next portion above the limb of the moon was about 6′, and it had a decided radial structure, especially near the outer limit. Its colour was silvery white. This portion seemed to be concentric with the sun, and its form was quite symmetrical, showing no change whatever in its outline in the vicinity of the protuberances The third and outer portion of the corona, on the western limb of the sun, consisted of three projections of light striated, or of a radial structure, resembling the short bands of streamers that are frequently seen rising from the auroral arch.

Lord Lindsay. 36° 38′ N. } 3° 12′ W. } MARIA LOUISA OBSERVATORY, 22nd Dec., 1870.

[Lord Lindsay made an attempt to photograph the corona in the principal focus of a reflecting telescope of 12 inches aperture and 6 feet focal length. The plate is unfortunately much fogged, so that even the great rift cannot be distinguished. The only detail of the corona that can be recognized is a brighter conical mass on the moon's western limb.]

Prof. J. Winlock. 36° 43′ 56″ N. } 6° 10′ 8″ W. } JEREZ DE LA FRONTERA, SPAIN, 22nd Dec., 1870.

"United States Coast Survey Report" for 1870, Appendix 16.

Instrument.—8. Telescope of 6 inches aperture, mounted equatorially, with clockwork from west dome [*i.e.* of Harvard College Observatory], for taking photographs, lens corrected for the chemical rays. 12. A telescope of 8 inches aperture, with equatorial mounting and clockwork, borrowed from Messrs. Alvan Clark and Sons for use in photography.

(p. 23.) Telescopes Nos. 8 and 12 . . . . were used in photographing the total phase—the first by Mr. Willard and the second by Mr. Mahony. As in 1869 the photographs were taken in the principal foci of the object-glasses of both instruments.* Guided by my experience in observing the eclipse of 1869, at Shelbyville, I had arranged the cameras for these telescopes in such a way that at the instant of totality the slides which were used for making instantaneous exposures of the plates for partial phases might be drawn out and thrown aside, so that there might be no danger of cutting off any part of the corona.

This apparatus, although rough in appearance, answered its purpose admirably in 1869. But on this occasion I was induced to allow another to be substituted for it, shortly before the eclipse. The new contrivance seemed very ingenious and unobjectionable; and not having sufficient time to consider it attentively, I supposed that it would answer as well as the old one. Unfortunately the slide of this apparatus could not be removed, and the opening in it was small; so that, in the best of the two photographs taken, part of the outer corona was lost, although the whole of the

* The focal length of these instruments is not given either in the "U. S. Coast Survey Report," or in Vol. viii. of the "Annals of the Harvard College Observatory."

inner corona seems to have been secured. Its outline is distinctly seen, surrounded by the fainter light, which alone was limited by the diaphragm.

The triggers which released the slide in the apparatus which was used required a light for their successful management, and the accidental blowing out of this light caused some confusion in the photographic work, which may have resulted in additional defects in the pictures obtained. . . .

(p. 24.) My plan was to take three photographs of the corona with the 6-inch and one only with the 8-inch telescope—that is, to leave the plate exposed in the latter during nearly the whole of the total phase, hoping that this large aperture and long exposure would secure the outer faint light, while the bright parts of the corona would be distinctly represented in the photographs made with the smaller instrument.

Everything was in readiness for carrying out this plan, but the discouraging aspect of the weather on the day of the eclipse, which is sufficiently described in the reports of my colleagues, made it hopeless to attempt so much. Accordingly, instead of giving directions for a certain number of exposures of specific duration, I simply directed the photographers to watch their opportunity, and to use their own judgment as to the time of exposure, guided by the intensity of the light modified, as it most likely would be, by the clouds. One good picture was, if possible, to be obtained with each telescope. The photographs actually taken during totality [were two], the first being taken by Mr. WILLARD,* and the second by Mr. MAHONY.

* Plate No. 5 has been made from a glass positive taken from Mr. Willard's negative which was given to Lord Lindsay.

A lithographic plate made directly from Mr. Willard's negative is given as plate 13 of Vol. viii., Part 2 of the "Annals of Harvard College Observatory"; and it will be noticed that the position of the sun's axis as marked upon this plate by Prof. Winlock agrees fairly with the orientation which has been adopted from a comparison with Mr. Brothers' Syracuse negative No. 5.

Prof. Winlock gives the following account of his determination of the position of the sun's axis as laid down on the plate in the "Annals of Harvard Col. Obs.," Vol. viii., Part 1, p. 63:—"The position angles on the margin of these engravings are counted from the north pole of the "sun through the east. They were obtained in the following manner: The camera remained "undisturbed from the beginning to the end of the eclipse; the edges of the glass plates were "straight and parallel. Hence, by placing the plate containing the total phase between two "plates showing partial phases before and after totality, I was enabled to determine the position "from the line of cusps with all the accuracy attainable in a diagram of the proportions of these "plates."

A lithographic plate from the negative obtained with Mr. Mahony's instrument is given as

Mr. A. Brothers.

37° 3′ 53″ N. } SYRACUSE,
15° 16′ E. } 22nd Dec., 1870.

MS. Observations of the 1870 Eclipse.

The Sheepshanks telescope No. 3 was placed at my disposal by the Royal Astronomical Society, but its focus was too long to give a sufficiently intense image for my purpose; I therefore determined to make use of a

plate 4 of Part 1 of Vol. viii. of the "Annals of Harvard Col. Obs." The original negative, which I had an opportunity of examining during a visit to Harvard in 1878, is evidently much over-exposed, and the light of the lower parts of the corona and prominences has encroached by irradiation some 4′ or 5′ over the limb of the dark moon, forming an even fringe, in which the irradiation from the prominences does not exceed (or only very slightly exceeds) that from other parts of the corona adjacent to the moon's limb. There are only three interruptions of the fringe, corresponding to the places of the three largest rifts, so that the two most conspicuous of the rifts appear to be continued by a narrow channel on to the disc of the moon. The appearance was so strange that Prof. Winlock, in his Coast Survey report, p. 24, says of this negative, "I do not know how to account for its appearance. Mr. Willard attributes it to the "shaking of the telescope by the wind. Inasmuch as the outer edge of the light fell clearly "inside of the mark of the diaphragm in the plate, I thought it worth while to have an engraving "made from this photograph, if only to show how far from the image of the moon the plate had "been affected by light from the corona, the aperture having been eight inches, and the time of "exposure, as nearly as I can ascertain, one minute and a half."

Although the lower parts of the corona are so greatly over-exposed, the extent of the corona as shown upon this negative is not nearly equal to the extent of the corona as shown upon Syracuse negative No. 5: a fact which might at first sight appear to raise a grave doubt as to the existence of the outer parts of the corona as depicted upon the Syracuse negative. But it must be remembered that the intensity of the image falling upon the photographic plate in Mr. Brothers' camera was probably considerably greater than the intensity of the image in the principal focus of the 8-inch telescope made use of by Mr. Mahony. And though the Syracuse negative was only exposed for seven seconds, faint parts of the corona may have registered themselves upon the photographic plate which, with a smaller pencil of light, failed to make any impression in a minute and a half.

The outline of the corona as shown in this negative is quadrilateral, but there are some striking differences between the form of the corona as shown on this negative, and the quadrilateral outline of the brighter parts of the corona as shown in Mr. Willard's and Mr. Brothers' negatives,—showing that the contours of equal brightness in the corona corresponding to contours of equal densities in the negatives, were far from being parallel to one another or symmetrically arranged with regard to the sun.

It should also be noticed that the band of irradiation about the moon's limb in Mr. Mahony's negative is of different breadths at different parts, so that the moon's limb appears not to be circular—the greatest projections no doubt corresponding with the places where the matter adjacent to the moon's limb was brightest.

The even outline of this irradiation band, as well as the gaps in it corresponding with the rifts, shows that there was irradiation from the lower parts of the corona as well as from the prominences.

photographic camera strapped to the telescope, which was mounted equatorially and driven by clockwork. For this purpose Mr. Dallmeyer kindly lent me one of his patent "Rapid Rectilinear" combinations, of four inches aperture and thirty inches focal length. It was found necessary, however, to cut down the effective aperture by means of a diaphragm to three inches.

When the totality commenced the moon was partly obscured by thin clouds, and it became evident that the plates would need longer exposures than those which had been previously planned. The times of exposure actually adopted were as follows:—

	Seconds of totality.	Seconds of totality.	Result.
Spare time	3		
1st Exposure	3	3rd to 6th	Blank.
Change plate	6		
2nd Exposure	18	12th to 30th	Fair.
Change plate	6		
3rd Exposure	30	36th to 66th	Slight.
Change plate	6		
4th Exposure	15	72nd to 89th	Fair.
Change plate	6		
5th Exposure	8	95th to 103rd	Best.
Space of time before end of totality about	3		
	104		

A picture was also taken in the Sheepshanks telescope camera with an exposure of three seconds, beginning at the thirty-sixth. This was for the purpose of recording the positions of the red prominences. The result was not good, the prominences showing only on the west side of the moon.

The photographs taken during this eclipse prove that the light of the corona is very actinic, and several photographs of this beautiful phenomenon may be taken during the time of totality. Judging from the effect of the coronal light on the sensitive plate, I should estimate its intensity near the moon's limb as quite equal to that of the full moon.

That it is impossible to obtain satisfactory photographs of the corona either with reflecting or refracting telescopes, *as ordinarily used*, is I think now conclusively proved.

The lens lent for the purpose of this expedition by Mr. Dallmeyer

Brothers' report. was in every way suitable for the purpose, and the image of the sun (or moon) although only $\frac{3}{10}$ths of an inch in diameter, was sufficient.

The corona is shown in three of the plates, and although these three pictures were taken through cloud, as much of the image is seen as is usually shown in negatives which have been taken in a telescope. The fourth picture, taken when the cloud had completely passed away, shows the corona extending in all directions. The 2nd, 3rd, and 4th plates all show the corona as being brighter on the west side, and the 5th plate exhibits this feature still more distinctly, and there can be no doubt that there was more light on the west side of the moon than at any other part. On the west side of the moon also it will be noticed that there are more of the red prominences than in any other part.

It is extremely difficult to describe the appearance presented by this 5th picture. I have attempted to show the effect in the accompanying plate,* which fairly represents the photograph, but the detail is so delicate that no process of copying can give an altogether satisfactory result.

* The orientation of the plate accompanying Mr. Brothers' report has been adopted for plate No. vi. There were no wires to mark the position of the north point; and no photographs were taken at Syracuse with the special object of determining the position of the equator of the heavens upon the totality photographs; except a plate, on which a trace was made by sweeping the image of the sun across the field. This cannot however be relied upon, as it is affected with the error in the position of the equatorial mounting of the instrument. It was therefore thought most prudent to rely upon the orientation which had been adopted by Mr. Brothers from his memory of the position of the photographic plate in the camera, and from a comparison which he had made with the position of the solar crescent on the plates in the partial phase pictures.

The mezzotint steel engraving for plate No. vi. has been made from a very conscientious drawing by Mr. W. H. Wesley of the detail visible upon Syracuse negative No. 5, as seen under various illuminations. The outer portions of the corona are best seen by reflected light, but the structure of the brighter parts of the corona is only to be made out with moderately strong transmitted light, such as a background of bright cloud or a clear sky. The prominences and some of the brightest parts of the corona are to be recognised on Syracuse negatives Nos. 2, 3, and 4, and match very well with one another and with negative No. 5. These negatives are now in the possession of the Royal Astronomical Society. In examining them they should be compared with Mr. Wesley's drawing, which is now deposited in the library of the Society. Although at first sight there does not appear to be much detail in this drawing, its production occupied Mr. Wesley nearly three months.

Eclipse of 1871, December 12th.

Photographic evidence.

The excellent photographs that were taken during the eclipse of the 12th of December 1871 afford better evidence with respect to the structure of the corona than we at present possess with regard to the coronas which have been observable during other total eclipses.* Five photographs in which the definition is very sharp were taken at Baikul, and six photographs on the same scale were taken at Dodabetta; and although the dark moon is represented by a circle only about $\frac{3}{10}$ths of an inch in diameter, and the whole field of the corona would be more than covered by a sixpence, an examination of the photographs under suitable illumination yields very satisfactory evidence as to all the structure represented in plates vii. to xvii..

Comparison of photographs.

It would be impossible, from an examination of a single negative, to determine whether any small marking has its origin in some minute impurity in the collodion, or whether it represents a structure in the corona; but by a comparison of the different negatives the photographic flaws can with certainty be eliminated. And a careful examination proves that all the coronal details which can be made out on the Dodabetta photographs can also be traced with certainty in the photographs of the Baikul series, in which the definition is rather sharper.

Drainage mark on Dodabetta photographs.

On a first examination there appeared to be some long straight rays on some of the Dodabetta photographs which were not to be seen in the Baikul series; but a closer examination showed that these long rays, some of which extended to a great distance from the sun's limb, were all parallel to one another and parallel to some semi-transparent channels which cut through and partially obliterated undoubted coronal structure.

* Photographs showing a great deal of coronal structure were taken during the eclipse of July 1878, but the details visible on them have not at present been drawn and catalogued. A cursory examination of the negatives proves that there was a great deal of difference between the structure as well as the general form of the corona on the two occasions. In the 1878 photographs the structures are more easily recognized, and they appear to have been somewhat coarser, and probably also brighter, as compared with the background on which they were projected, than in the corona of December 12th, 1871. The tree-like forms, as well as the synclinal groups, which were a marked feature of the corona of December 12th, 1871, appear to be absent in the corona of July 1878.

Description of Plate IX.

Plate ix. has been made from negative No. 1 of the Dodabetta series, and shows the long rays and transparent channels referred to. It will be noticed that they are all approximately parallel to one another and to the edge of the photographic plate. Two of the transparent channels may be faintly traced across the disc of the moon, and another in the fogged area towards the top of the plate; and there can be little doubt that both the long rays and the transparent channels are due to drainage marks caused by the photographic plates having been set up to dry before they were sufficiently washed.

Irradiation from the prominences.

Plate ix. also shows very well the irradiation from the prominences extending over the disc of the dark moon—a phenomenon which is common to all corona photographs, and proves the great actinic intensity of the light of the prominences as compared with the coronal matter adjacent to other parts of the moon's limb.

In the south-east section of the corona as shown in negative No. 1 of the Dodabetta series is an opaque mass with a definite upper limit which seems to have been caused by some photographic action similar to that which gave rise to the broad band of opacity round the moon's limb in Mr. Mahony's Jerez photograph of the corona of 1870. There is a similar though larger mass in another photograph of the Dodabetta series; but with the exception of these masses there is nothing to indicate any concentric structure in the corona, such as we might expect would correspond to a region of dissociation or to any other abrupt change in the physical state of the coronal matter.

No concentric structure in the corona.

Catalogue of structures visible in the photographs.

In order to exhibit the evidence which exists for each of the coronal structures given in the plates, a catalogue has been prepared containing a list of the negatives upon which each detail can be distinguished. In this work I had the good fortune to be aided by a most accurate and conscientious artist (Mr. Wesley, the present Assistant-Secretary of the Royal Astronomical Society), for whose laborious perseverance in the task I cannot be too thankful. Before any detail of coronal structure was entered in the catalogue, it was drawn by each of us separately; and unless our drawings agreed and we recognised the structure upon three of the negatives, it was not entered in the catalogue.

In some of the photographs the structure of the lower parts of

the corona is all that can be made out, while in others the middle heights are best seen, the highest parts of the corona being lost, and the lower parts merged in a nearly opaque mass, by reason of overexposure. Again, on any one negative all the details cannot be seen at the same time,—they only become visible as the plate is examined with different intensities of light: for example, the prominence structure can only be made out with magnifying powers and strong transmitted light,* whereas the structure of the corona at a height of from 5′ to 15′ can only be seen on the background of a bright sky, and is completely lost when a lens is used. The highest parts of the corona, which can in some instances be traced to a distance of 26′ from the sun's limb, can only be seen by reflected light.

Examination of the photographs.

Plates x. to xvii. show, on a scale of ten inches to the sun's diameter, the structures which have been entered in the catalogue. The distinctness of the coronal details has been intentionally exaggerated, for it would have been impossible to reproduce by lithography the delicate differences of opacity to be seen in the negatives; and if it had been possible, the plates would not have been so serviceable as diagrams to compare with the descriptions of the structures given in the catalogue. Plates vii. and viii. more nearly represent the appearance of the photographs, though in these the structures have necessarily been made somewhat more conspicuous than they appear on the photographs, even as seen under the most favourable circumstances.

Java photographs.

In addition to the photographs taken at Baikul and Dodabetta, two photographs of the corona were taken at a station near Tjebatjap, in Java, with an ordinary photographic camera and exposures of ½ and ⅓rd of a second. Enlarged glass positives from these photographs which have been sent to this country show many details in the outer parts of the corona, which can be readily recognised as corresponding with details shown in the Baikul and Dodabetta negatives. The structures which can be recognised in the Java photographs are referred to and described in the catalogue, and it will be noticed that there is no evidence of change having taken place in the form of the coronal

* I am indebted to Lord Lindsay for the loan of an oxy-hydrogen lamp, with which the lower parts of the negatives were examined, and for a very convenient apparatus which he had specially constructed for the measurement of position angles upon the negatives.

structures, as far they can be recognised,* during the period of an hour and four minutes which elapsed between the times of mid-totality at Baikul and the Java station.

Jaffna photographs.

Photographs were also taken at Jaffna by Capt. HOGG, but they are so fogged that very little use has been made of them. As far as the coronal structures are recognizable in them, they appear to correspond with the Baikul and Dodabetta negatives. About three minutes elapsed between the times of mid-totality at Baikul and Jaffna, and about one minute between the times of mid-totality at Baikul and Dodabetta.

Orientation of plates.

Plates vii. and viii. have been oriented by means of a photographic plate taken by Mr. DAVIS at Baikul. A little more than half an hour before totality the driving clock of the camera was stopped, and five photographs of the solar crescent were taken at intervals of six minutes. After totality the same plate was again exposed, and another series of images of the solar crescent photographed upon it. The position of the equator of the heavens, determined by placing a straight edge tangentially to the first series of images and thus measuring the inclination of a tangent line to the solar images with the edge of the plate which was lowest during the exposure, is practically identical with the position of the equator of the heavens, determined in a similar manner from the second series of images. All the plates fit loosely into the exposing frames; and in laying down the position of the projection of the sun's axis upon the photographs, it has been assumed that the lower edge of the orientation plate, and of the plates which were exposed during totality, were all similarly situated with respect to the camera. Having determined the position of the line corresponding to the projection of the equator of the heavens upon the plates, the sun's axis was laid down as 11° 40′ to the east of the north point. The position of the projection of the sun's axis laid down in this manner upon all the plates is practically identical with respect to the coronal details, and it may probably be assumed that, including errors of copying, the orientation of the corona as shown in plate vii. is not 2° in

* If we take into account the small scale of the photographs, and the enormous magnitude of the coronal structures, it will be evident that the matter of the corona may have been moving with velocities which were great compared with the velocity of the earth in its orbit, without any sensible change, such as would be recognisable in the photographs, being brought about in a period of one hour.

error. Plate viii., made from the Dodabetta photographs, has been oriented to correspond with plate vii.

The longest rays of the corona as shown upon the Baikul photographs do not reach to a height of 27′ above the sun's limb, while in the Syracuse photograph of the corona of 1870 the corona is traceable to a height of at least 40′ above the sun's limb. In the Dodabetta photographs the extent of the corona is not quite as great as in the Baikul series; and in the copies of the photographs taken in Java the corona does not extend to a height of much more than 15′ above the sun's limb. But, according to the evidence of Capt. HERSCHEL and Capt. TUPMAN, the corona must have been visible to a much greater distance above the sun's limb. Capt. HERSCHEL describes the longer rays seen without a telescope as extending to "one and a half diameters" from the moon's limb; and Capt. TUPMAN, observing with a telescope, describes a narrow rift in the north-west region of the corona as "distinctly traceable to a distance of 45′ or 50′ from the moon's limb.

Extent of the corona.

Judging by the descriptions of observers, and the drawings made during this eclipse, it seems probable that the structures in the lower part of the corona, up to a height of say 25′ above the sun's limb, were considerably more striking—that is, brighter, compared with the background on which they were seen projected—than in the corona visible during the eclipse of December 1870.

Coronal structure very striking during this eclipse.

The Dodabetta negative No. 5, which was only exposed for five seconds, and the Baikul negatives Nos. 2 and 4, which were each exposed for ten seconds, are considerably denser up to a height of 20′ than the Syracuse negative No. 5, which was exposed for seven seconds. But it must be remembered that the Syracuse photograph was taken through a gap in passing clouds, and the lens of the camera, which was similar to those made use of at Baikul and Dodabetta, was stopped down in the Syracuse instrument by a diaphragm to only three inches, thus cutting off nearly half the light. The altitude* of the eclipsed sun as seen from

Lower parts of the corona probably brighter than during the eclipse of 1870.

* It is well known that as the sun approaches the horizon, the absorption at the violet end of the solar spectrum increases very rapidly. And if the spectrum of the greater part of the light of the corona is richer in short wave-lengths than the solar spectrum, as suggested on pp. 352 to 353, the photographic intensity of an image of the corona would decrease still more rapidly than the photographic intensity of the sun's image on approaching the horizon.

Syracuse was 22° 46′, while the altitude of the eclipsed sun as seen from Baikul was 15° 33′, and from Dodabetta 17° 5′. The outer regions of the corona, from a height of 25′ to 40′, appear to have been considerably brighter in the corona of Dec. 21st, 1870, than in the corona of Dec. 12th, 1871.

Evidence to be derived from drawings and descriptions of the corona.

The six great groups of coronal structures and the two striking polar rifts seem to have been remarked by many of the observers, though not by all. Capt. HERSCHEL was of opinion that the separate character of the groups was more marked as seen with the naked eye than in the photographs; but the groups of rays are not shown in many of the drawings, and the woodcuts chiefly serve to show how inferior the evidence to be derived from drawings is, compared with that to be derived from photographs, especially when an attempt was made to make more than one drawing of the corona during totality. Several printed forms of questions with answers by natives and other unskilled observers are preserved in the collection of MS. Reports of the 1871 Eclipse Expedition, now in the library of the Royal Astronomical Society; but only the answers of Messrs. Pillay and Annappa have been printed, and they serve as a specimen of the unsatisfactory nature of such evidence.

General remarks with respect to change in the appearance of the coronal structures as seen in perspective.

The arrangement with respect to the sun's axis of the structures visible in the Baikul and Dodabetta photographs has been discussed on pp. 485-8. In addition to the remarks there made with regard to the changes which may be caused in the appearance by their being seen in the perspective, it may be well to add that—

A straight ray cannot by projection be seen as curved—nor could a curve of single curvature be projected into a curve exhibiting contrary flecture.

And though a ray which is not normal to the sun's surface may as seen in perspective appear radial to the sun's limb, a ray which does not appear radial to the sun's limb cannot be normal to the sun's surface.

We may therefore assert that some of the coronal rays were certainly not normal to the sun's surface. And there appears to be ample evidence that some of the coronal structures curved in different directions

Atmosphere in coronal regions.

at different altitudes, apparently indicating the existence of an atmosphere in the coronal regions, with currents carrying the matter of which the

structures were composed in different directions or with different velocities at different altitudes.

The evidence for the existence of branching rays is less conclusive, for two curved rays seen in projection might appear as a single branching ray; but some of the coronal structures, as for example Hγ and Hβ, can probably hardly be accounted for on such a supposition. **Branching rays.**

Catalogue of Details visible in Photographs of the Corona of 1871, *Dec.* 12*th*.

Definition of terms used in catalogue. None of the details of the corona as shown in the photographs can be spoken of as being sharply defined; but the following words have been chosen to signify the various degrees of definiteness:—1. Sharp. 2. Soft. 3. Woolly. 4. Fluffy. These words are used when there is a decided difference between the opacities of the object and its background.

The terms Hazy and Foggy are used when there is but little difference between the opacities of the object and its background; the adjective Foggy corresponds to a much greater degree of indistinctness than Hazy.

The word Dark is used to signify opacity of the collodion film as seen by transmitted light. Rifts are therefore spoken of as bright, and rays as dark.

In estimating the inclination to the radial of a ray or other detail, the angle is always measured from a radial line drawn through the apparent base of the object under description.

For convenience of reference in the following catalogue, the coronal details are divided into nine groups, distinguished by the letters of the alphabet from A to I. These groups are shown on a scale of ten inches to the sun's diameter on plates x. to xvii. Each structure or group of coronal details, the evidence with respect to which is separately examined, is distinguished by a Greek letter, as well as by the capital letter corresponding to the group to which it belongs.

The height of the coronal structures is measured perpendicularly from the estimated place of the photosphere behind the moon's limb.

The photographs of the Baikul series are distinguished as B 1, B 2, etc.; those of the Dodabetta series as D 1, D 2, etc.; and the copies of the two Java photographs as J 1, J 2.

PLATE X.

A α.—A nebulous mass, or ray, forming a background* to β and part of γ; its height is about 14′. It is distinctly separated from the needle ray in the centre of the north polar rift, but less distinctly separated from A γ. Its axis of symmetry is decidedly inclined from the radial towards the east.

B 1. Distinctly visible. Its separation from γ is well shown in this negative.

B 2. Quite lost.

B 3. Just perceptible, but very nearly lost in the general haze.

B 4. About as well seen as in No. 1.

B 5. Quite visible, though not so distinct as in Negatives 1 and 4; but its separation from β is well marked.

D 1. Well seen.

D 2. Scarcely visible, in consequence of a transverse streak.

D 3. Moderately well seen.

D 4. Lost, or possibly just visible.

D 5. Lost.

D 6. Lost.

J 1. The whole group A is distinctly divided into three separate masses, but the individual details cannot be recognized.

J 2. There is not so much extension as in J 1, but the three groups are visible as separate masses. And in both J 1 and J 2 a faint division is recognizable in the northern, which is possibly the northern edge of A β.

A β.—A slightly curved ray, about 7′ high, inclined from the radial towards the east. It forms a sort of spur to the larger mass A γ; its western edge is slightly convex towards the centre of the A group. Its axis of symmetry makes an angle of about 30° with the radial.

B 1. Distinctly visible, though its outline is very soft; the division between β and γ can be traced to a depth of only about 5′.

B 2. Quite lost.

B 3. Distinctly visible, but very fluffy; the division between β and γ can be traced to a depth of between 3′ and 4′.

B 4. Outline sharply defined; its form is better seen in this negative than on any other, but there is a minute flaw near to the junction of β and γ.

B 5. Distinctly recognizable, but its outline is exceedingly indistinct. The division between β and γ can be traced to a depth of between 3′ and 4′.

D 1. Distinctly visible, though woolly.

D 2. Just visible as separate from A γ.

D 3. Moderately well seen, though fluffy.

D 4. The division between β and γ is quite lost.

D 5. Lost.

D 6. Quite lost.

A γ.—About 17′ high, inclined from the radial towards the east. It has an appearance of double curvature, and is decidedly concave towards the centre of the A group in its upper half.

B 1. Distinctly visible.

B 2. Only its base is seen, which is merged with β and δ.

B 3. Its upper portion is just traceable; the whole very woolly.

B 4. Its lower portions are best seen in this negative, but there is a minute flaw at its junction with β.

B 5. Very woolly, but it has considerable extension.

D 1. Very well seen in its upper portions.

D 2. Visible, but cut across by a transverse streak.

D 3. Visible, but very fluffy.

D 4. Its outline is quite lost.

D 5. Only its base can be made out.

D 6. Quite lost.

* By the word background it is not intended to indicate that α lies behind β: it may really envelope β, or be actually in front of both β and γ.

A δ.—About 7′ high, concave towards the centre of the A group, forming a sort of spur to γ. Its eastern side is the most definite; at its base it is slightly inclined from the radial towards the north.

B 1. There is a minute flaw which prevents its lower parts from being recognized. Its upper part is very soft and woolly, and its inclination towards the east is not so distinctly to be recognized as in Nos. 3 and 4.

B 2. Its base is distinctly visible, its upper portion very faint.

B 3. Very hazy, but distinctly visible, especially at its base. The division between γ and δ is also well shown.

B 4. It is best seen in this negative.

B 5. A small scratch cuts right across its upper part. The whole is very hazy, but can be distinctly recognized.

D 1. Not well seen.

D 2. The division between γ and δ is well seen, but the eastern edge of δ is very foggy.

D 3. About as well as D 2.

D 4. Quite merged with γ.

D 5. Lost.

D 6. Quite lost.

A ϵ.—A nebulous field, apparently without detail, which faintly extends higher than γ, and appears, when seen by reflected light, to envelope the whole of the northern part of the A group.

B 1. Well shown.

B 2. Lost.

B 3. Visible, but its outer parts are lost in the surrounding haze.

B 4. Well shown in this negative.

B 5. It has, perhaps, a larger extension in this than in the other negatives.

D 1. Well shown.

D 2. Cut across by a streak. Not well seen.

D 3. Visible, though the extension is not very great.

D 4. Its upper part is quite lost.

D 5. Lost.

D 6. Quite lost.

A ζ.—A small curved structure, about 4′ high. It is very indistinct, but its stem seems inclined from the radial about 30° towards the east.

B 1. A small flaw renders it barely visible.

B 2. Lost.

B 3. Hazy, but distinctly visible.

B 4. Its upper part comes out well, but the collodion is too opaque near to the sun's limb to allow of its lower part being made out satisfactorily.

B 5. Traceable, but hazy.

D 1. Just traceable.

D 2. Just traceable.

D 3. Visible as a dark lump.

D 4. Lost.

A η.—About 7′ high, convex towards the north; at its lower part it appears to be decidedly inclined from the radial towards parallelism with the base of A β and A γ. At a height of about 5′ it turns sharply to the north. Its western edge is the best defined.

B 1. Well seen, but its upper part is slightly woolly.

B 2. The upper part seems quite lost.

B 3. Visible, but very hazy.

B 4. Its upper part is well seen on this negative.

B 5. Visible, but very hazy.

D 1. Distinctly visible, but very fluffy.

D 2. Well seen, but fluffy.

D 3. Visible, but woolly.

D 4. Only just traceable.

A θ.—About 11′ high. It is divided at its summit into two branches, which curl over in opposite directions; the western branch is rather the larger. Its stem appears quite straight, and is inclined from the radial towards the east so as to be nearly parallel

with the lower parts of A β and A γ; though its inclination towards the east is somewhat greater, its inclination to the radial is somewhat less than that of A β, and A γ, being not quite 20°.

B 1. There are two minute photographic flaws about symmetrically placed upon the two branches; but with this exception the whole is well seen.

B 2. Quite lost, except an indication of the long straight stem.

B 3. Very hazy, but visible.

B 4. The whole is well (perhaps best) seen on this negative.

B 5. Visible, but very woolly.

D 1. Distinctly traceable, but woolly.

D 2. Its summit cut across by a photographic defect.

D 3. Rather more easily to be traced than in D 1, but woolly.

D 4. Distinctly traceable, but hazy.

D 5. Lost.

J 1. The group A is distinctly shown as divided into three separate masses, but none of the details can be recognized with certainty.

J 2. Though the central group has not so much extension as in J 1, yet it shows more traces of structure. A η, A θ, and possibly A ζ, are faintly discernible.

A ι.—About 7′ high, forming a sort of spur to A θ, on the opposite side from η. Its lower part is evidently inclined from the radial towards parallelism with the lower parts of A β and A γ. The curvature of its upper part is not so marked as that of B η.

B 1. Distinctly seen, but rather hazy.

B 2. Quite lost.

B 3. Very distinctly seen. Its upper part is quite sharp.

B 4. Best seen in this negative.

B 5. Very hazy, but just visible.

D 1. Just visible.

D 2. Quite visible, moderately well seen.

D 3. Well seen.

D 4. Moderately well seen.

D 5. Lost, or only just visible.

A κ.—About 16′ high; its summit is the only portion visible. It appears to lie behind A λ, and the rest of the details of the A group. Judging from the inclination of the part visible, it appears to be inclined from the radial towards the east at a greater angle than the stem of A θ.

B 1. Distinctly visible.

B 2. Quite lost.

B 3. Quite lost.

B 4. Very well seen; its eastern edge is better defined than its western.

B 5. Visible, but very hazy.

D 1. Visible, but hazy.

D 2. Lost.

D 3. Only just visible.

D 4. Lost.

D 5. Utterly lost.

A λ.—About 15′ high; its eastern edge crosses the western edge of A κ at a height of about 12′. Only the upper part is clearly to be made out; it appears to spring from amongst the general mass near the base of o. The part which is visible is decidedly inclined from the radial towards the north. It is more distinct than A κ.

B 1. Very clearly seen.

B 2. Quite lost.

B 3. Only just traceable; very foggy.

B 4. Very clearly seen.

B 5. Quite visible, but hazy.

D 1. Clearly seen, though hazy.

D 2. Lost.

D 3. Only just visible.

D 4. Lost.

D 5. Utterly lost.

A μ.—A nearly structureless mass, the intensest part of which is decidedly inclined from the radial towards the west. On its northern edge, and close to the lower parts of A θ and A ι, is a small lighter space, whose centre is at a distance of about 3′ from the moon's limb. A μ appears to pass upwards, behind A ι. It is bounded on its western side by A ν, and higher up by an elliptical lighter space, whose longer axis is inclined towards the west.

B 1. Moderately well seen.

B 2. Its western edge is distinctly traceable; it seems parallel to the lower part of A θ, but the whole is hazy.

B 3. Just visible.

B 4. Clearly seen.

B 5. Moderately well seen.

D 1. Visible, but very woolly. The light space is nearly lost.

D 2. Moderately well seen. The light space is clearly marked.

D 3. Moderately well seen, but woolly.

D 4. Visible, but not well seen.

D 5. Just visible.

A ν.—An indistinct triangular mass, about 4′ high; its axis of symmetry appears to be inclined towards the west, and to be slightly concave towards the centre of the A group.

B 1. Distinctly visible, but woolly.

B 2. There is a little black flaw in its place; it seems to be quite lost.

B 3. Visible, but hazy.

B 4. Clearly seen with a strong transmitted light.

B 5. Distinctly visible, but hazy.

D 1. Only just visible.

D 2. Its summit just visible.

D 3. Moderately well seen, though woolly.

D 4. Visible, but very woolly.

D 5. Lost.

A o.—About 8½′ high. It appears to be a two-branched structure, the main stem of which has a slight concavity towards the centre of the A group, and is decidedly inclined from the radial towards the north-west. The western branch is slightly the longer, and rather more distinctly to be made out than the other.

B 1. Well seen, but on none of the negatives is it a marked feature.

B 2. The western branch is just visible.

B 3. Distinctly visible, but woolly.

B 4. Its upper part is well seen on this negative.

B 5. Visible, but hazy.

D 1. Visible, but exceedingly woolly.

D 2. Visible, but very woolly; rather interfered with by streaks at its summit.

D 3. Moderately well seen, though woolly.

D 4. Moderately well seen, but very hazy; separated from A π by a flaw at a height of about 5′.

D 5. Almost lost; its form cannot be traced.

J 1. The group of structure formed by A o, A π, etc., is distinctly visible as a separate mass. Part of the summit and the northern curving edge of A o can be made out. Also the straight southern edge of A π, and the rift separating it from B α.

J 2. There is not so much extension as in J 1; but the double summit of A o, and its northern curving edge, can be well made out.

A π.—A slender, apparently straight ray, about 16′ high, inclined from the radial at an angle of about 25° towards the north-west. It therefore appears to be nearly parallel with the lower part of A β, A γ, and A θ. Its south-eastern edge appears much the

sharpest; but this is perhaps by contrast with the bright field of the adjacent rift, of which it forms the north-western boundary.

B 1. Very distinctly visible.
B 2. It seems quite lost on this plate.
B 3. Faint, but quite visible. At a height of about 13′ it is interrupted by a minute black flaw, which extends into the rift.
B 4. Very distinctly visible.
B 5. Distinctly seen, but hazy.

D 1. Well seen.
D 2. Distinctly visible.
D 3. Well seen.
D 4. Visible, but very hazy.
D 5. Lost.

J 1. Visible, though interfered with by a flaw which runs parallel to it.
J 2. Just traceable.

A ρ.—A ray about 13′ high; it appears to spring from behind A σ. Its south-eastern edge is the most definite, and is decidedly convex towards the central parts of the A group. It seems not improbable that A ρ and A σ may be two branches of a structure similar to A *o*.

B 1. Visible, but scarcely distinct from A σ. Very soft.
B 2. Quite lost.
B 3. Its south-eastern edge is just visible.
B 4. Well seen in this negative.
B 5. Visible, but very woolly.

D 1. Moderately well seen, though hazy and merged with A σ.
D 2. Visible, but very hazy.
D 3. Distinctly visible, though merged with A σ.
D 4. Only just visible; very foggy.
D 5. Quite lost.

A σ.—About 11½′ high. Its upper part appears to be concave towards the centre of the A group, but it is much fainter than A ρ.

B 1. Just visible; very woolly.
B 2. A bright streak cuts across this part of the negative; it may possibly just be seen, but can be spoken of with no certainty.
B 3. Barely visible; very hazy.
B 4. Distinctly visible.
B 5. Only just visible; very hazy.

D 1. Visible, though merged with A ρ.
D 2. Lost.
D 3. Visible, though merged with A ρ.
D 4. Visible as a hazy mass, merged with A ρ.
D 5. Lost.

A τ.—About 11′ high. It appears to spring from behind A *o*, and to be decidedly inclined from the radial towards the north-west. The whole is very faint.

B 1. Only just traceable.
B 2. Quite lost.
B 3. Quite lost in a nebulous mass.
B 4. Very distinctly seen on this negative.
B 5. Just visible, but very faint.

D 1. Distinctly visible.
D 2. Lost.
D 3. Lost, or only just visible.
D 4. Lost.
D 5. Lost.

A ψ.—A nebulous field, which appears to envelope the whole of the eastern division of the A group. It is best seen on the negatives by reflected light, and may thus be traced to a height of at least 18′. Its greatest extension is towards the east; northward it falls off in intensity, producing the appearance of a rift (which reaches to a

depth of about 13′) between it and the upper part of the central mass of the group.

B 1. Well seen.
B 2. Quite lost.
B 3. Visible, but interfered with at the summit by a photographic flaw.
B 4. Well seen.
B 5. Well seen.

D 1. Very great extension, though it is interfered with by a transparent channel parallel to the edge of the plate.
D 2. Lost.
D 3. Well seen.
D 4. Well seen, though its upper part appears rather abruptly cut off.
D 5. Lost.

A ξ.—A curving structure, concave towards the centre of the A group; its summit becomes nebulous, and seems to lose itself in A *o*, at a height of about 4′.

B 1. Well seen.
B 2. Well seen on the background of a bright sky.
B 3. Just traceable.
B 4. Just visible, but very opaque.
B 5. Distinctly visible, but its summit is interfered with by three dark patches.

D 1. Just traceable with a low power microscope, but very opaque.
D 2. Just traceable; very woolly.
D 3. Only just traceable; very opaque.
D 4. Lost.
D 5. Just traceable.

A ϕ.—A branching structure, nearly 5′ high. Its eastern branch is the most distinct.

B 1. Very well seen.
B 2. Visible.
B 3. Distinctly visible.
B 4. Well seen, especially with strong transmitted light.
B 5. Visible, but hazy.

D 1. Visible, but woolly.
D 2. Traceable, but very woolly.
D 3. Only just traceable; its summit is interfered with by a minute black flaw.
D 4. Just traceable; very foggy.
D 5. Possibly just traceable.

Plate XII.

B α.—An apparently straight ray, about 20′ high. It appears to be nearly radial, or but slightly inclined towards the north. Its northern edge, which bounds the rift, is less definite than the southern edge of A π. It is not distinctly recognizable as a separate ray below the height of 6′, where it appears to spring from behind the eastern boundary of the A group.

B 1. Well seen in this negative.
B 2. It appears to be quite lost.
B 3. Distinctly seen, but its division from B β is not definite.
B 4. The whole of the ray as given in the plate is well seen; but in its upper part it appears divided into two smaller parallel rays. As this detail has not been distinctly made out in any other of the negatives, it has not been included in the general description. Its presence may, however, be suspected in B 1, B 5, and D 3.
B 5. Well seen, though rather woolly.

D 1. Distinctly visible; cut across obliquely by a brighter channel parallel to the edge of the plate.
D 2. Lost; its place is occupied by a flaw.
D 3. Very well seen; it can be distinctly made out as double.
D 4. Distinctly visible, though woolly.
D 5. Lost.

J 1. Distinctly to be made out, though merged into a hazy mass with B β.
J 2. Lost.

B β.—A nearly straight ray, about 20′ high, apparently parallel to B a; at a height of about 15′ it rather markedly decreases in brightness. The whole is much fainter than B a, and cannot (except on its southern edge) be traced below the branch of B ϵ.

B 1. Well seen, especially its upper part.
B 2. Quite lost.
B 3. Just visible; very hazy.
B 4. Well seen.
B 5. Visible, but very hazy.

D 1. Only just visible, as distinct from B α. Seriously interfered with by the bright channel.
D 2. Lost.
D 3. Well seen.
D 4. Distinctly visible, though hazy.
D 5. Lost.

B γ.—A branching structure, about 4′ high. Its stem is decidedly inclined from the radial towards the north.

B 1. Very well seen on this negative.
B 2. Distinctly visible.
B 3. Just visible, but it can certainly be made out.
B 4. Visible, but very opaque.
B 5. Very well seen.

D 1. Only its summit is visible; the rest is lost in a dense mass, which reaches to a height of over 3′.
D 2. Only just traceable; very opaque.
D 3. Just traceable.
D 4. Lost.

B δ.—A branching structure, about 4′ high. Its stem is decidedly inclined from the radial towards the north. Its southern branch appears to form a spur to B ϵ, and its northern branch stretches out so as nearly to touch B γ.

B 1. Well, and probably best, seen in this negative.
B 2. Very distinctly seen.
B 3. Distinctly visible, though its outline is woolly. It is cut across by a photographic defect.
B 4. Distinctly seen, though the photograph is so opaque that it needs a very bright light.
B 5. Distinctly seen with a bright light.

D 1. Its summit is visible above a dense mass, which stretches all along the moon's eastern limb.
D 2. Visible, but foggy.
D 3. Distinctly visible, but woolly.
D 4. Just traceable.
D 5. Its stem is distinctly to be made out.

B ϵ.—A remarkable branching structure, which resembles in shape a very common type of solar prominence. Its southernmost branch extends to a height of about 11′, and its northern to a height of about 9½′. Its stem at its lower part is double; though, possibly, this appearance is due to a smaller branched structure lying in front of the great one. At a height of between 3′ and 4′ the two stems appear to join, and immediately above this a curved spur is thrown out towards the north, while towards the south a branch appears to extend upwards, and is seen as a darker mass upon the background of the great southern branch. The axis of symmetry of the whole structure is considerably inclined from the radial towards the north. A distinct double curvature may be traced about each of the edges of its two great branches. The northern one is not a simple homogeneous mass, but opaque details can be traced within it. The

most marked feature is a spur pointing upwards, near to the point where the northern branch turns sharply over and diverges from the southern branch.

B 1. The whole is well seen, especially its lower parts.

B 2. Well seen, though hazy towards its summit. The double curvature comes out very markedly.

B 3. All its parts are distinctly visible, although they are rather woolly, and the whole is cut across by a photographic flaw.

B 4. The whole well seen.

B 5. The whole is well seen.

D 1. Well seen, though woolly.

D 2. The whole is distinctly visible, but its upper parts are not well made out.

D 3. Well seen, though woolly.

D 4. Visible, though all its details, except its double base and the division between the two great branches, are lost.

D 5. Visible, though even more hazy than in D 4.

J 1. Its summit is distinctly to be made out, as well as the curvature of the southern branch.

J 2. A photographic flaw prevents the northern branch from being seen, but the southern branch is well shown.

B η.—A nebulous field, apparently without structure, which appears to envelope the whole group B. It is so opaque that, as seen by reflected light, even B ϵ is undistinguishable; it fades off gradually, and extends to its greatest height on the side towards the C group, where it can be traced to a height of about 20′. The bright arc which is described under the heading C ζ is clearly to be traced as interfering with the equal intensity of the field of B η. Towards the north an area of slightly greater intensity can be traced in most of the negatives. It fills the angle between the northern branch of D ϵ and the upper part of D β.

B 1. Well seen. Its extension greatest in this negative.

B 2. Quite lost in the fogging of the plate.

B 3. Not well seen.

B 4. Well seen, but extension not great.

B 5. Well seen; considerable extension.

D 1. Well seen. Its extension is very great, but towards the north it is interfered with by a bright channel parallel to the edge of the plate, and towards the south there is a somewhat darker area, above C ζ, which gives the appearance of a nebulous extension at the summit of C α.

D 2. Small extension. It is interfered with towards the north by photographic flaws.

D 3. Well seen, though the extension is not great.

D 4. Extension is not quite so great as in D 3.

D 5. Lost.

Plate XI.

C α.—A nearly straight ray, extending to a height of quite 25′. Its position with regard to C β makes it difficult to determine what is its axis of symmetry; but its general direction is not radial, and it appears to be inclined a few degrees towards the north. At a height of 15′ it throws off two faint branches, which make an angle of about 45′ with the main stem, and slightly curve away, one towards the north and the other towards the south.

B 1. Very well seen.

B 2. Its lower part only just visible.

B 3. Just visible, but foggy. Cut across obliquely by a photographic defect. The small branches are quite lost.

B 4. Very well seen, though not so well as in B 1.

B 5. Very hazy, but visible.

D 1. At a height of about 10′ it is cut across obliquely by a narrow channel parallel to the edge of the plate. Its summit appears enveloped in a hazy cloud, which can be traced to more than 40′ from the moon's limb. The faint branches are quite visible.

D 2. Only its lower part is visible.

D 3. Moderately well seen; the faint branches are just traceable.

D 4. Very woolly; the upper part is quite lost.

D 5. Only the lower part is visible.

J 1. The three rays, C α, C β, C γ, are merged in one common mass, which can be traced to a height of over 15′.

J 2. A mass which evidently represents C α, C β, and C γ merged in one is visible, but it cannot be traced so far as in J 1.

C β.—A long, straight ray, nearly radial, but slightly inclined towards the south. It extends to a height of quite 26′, as seen by reflected light.

B 1. Well seen; greatest extension in this negative.

B 2. Quite lost.

B 3. Lost, or only just visible. It is greatly interfered with by a photographic defect, which passes obliquely across its place.

B 4. Well seen.

B 5. Scarcely visible as distinct from C α and C γ.

D 1. Its place is occupied by a bright streak parallel to the edge of the plate.

D 2. Quite lost.

D 3. Moderately well seen.

D 4. Merged with C α and C γ into a nebulous mass

D 5. Possibly just traceable.

C γ.—A long, straight ray, decidedly inclined from the radial towards the south. It extends to a height of quite 26′, as seen by reflected light. Seen by transmitted light, it appears to be rather longer and slightly more intense than C β.

B 1. Well seen; very distinctly divided from C β.

B 2. Quite lost, except perhaps to a height of 10′, to which a dark mass can be traced, which probably forms the base of C γ and C β.

B 3. Scarcely visible as distinct from C α and C γ.

B 4. Well seen.

B 5. Just visible, as distinct from C α and C γ.

D 1. Lost in a hazy mass, which extends parallel to the edge of the plate to a distance of more than 40′ from the limb of the moon.

D 2. Quite lost as a separate ray.

D 3. Visible, but hazy.

D 4. Lost as a separate ray.

D 5. Lost.

C ϵ.—A minute, bright spot, about 9′ from the sun's limb. It appears to encroach on the northern edge of C β, and to touch the top of C δ. It is best seen upon the background of a clear sky.*

B 1. Distinctly visible.

B 2. Distinctly visible.

B 3. Distinctly visible, though not so clearly marked as in B 1, B 2, and B 4.

B 4. Distinctly visible.

B 5. Just visible.

D 1. Visible.

D 2. Distinctly visible.

D 3. Distinctly visible.

D 4. Only just to be made out, and not with certainty.

D 5. Only just visible.

D 6. Lost.

C ζ.—A bright arc, about $1\frac{1}{2}$′ broad, with a radius of about 6′; it appears to be concentric with C ϵ, and is concave towards the sun. At its summit it is about 15′

* For a further description of this bright spot and the concentric bright arcs C ζ, C η, which must have corresponded to a dark object absorbing the light of the bright details of the corona, see the "Monthly Notices," vol. xxxiv., pp. 365-9, where it is suggested that the appearance may possibly have been due to a comet situated between the earth and the corona.

above the sun's limb. On the south it cuts across C γ, C β, C α, and on the north extends to a distance of about 4′ on to the area of B η.

B 1. Very distinctly seen.
B 2. Quite lost.
B 3. Just visible.
B 4. Very distinctly seen.
B 5. Distinctly seen, though not so clear as in B 1 and B 4.

D 1. Visible through its central portions are interfered with by a streak.
D 2. Just visible; at first sight it appears to be traceable down as far as the southern branch of B ϵ. But possibly this part of the curve is formed by a photographic defect which gives a distinctly parabolic appearance to the arc.
D 3. Distinctly visible.
D 4. Distinctly visible.
D 5. Lost.
D 6. Lost.

C η.—The traces of a circular arc, much fainter than C ζ. It appears to be concentric with C ϵ, and has a radius of about 3′. The rays C α, C β, and C γ can be distinctly traced through it, and appear almost to break it up into three bright spots. An outer concentric circular arc, with a radius of about 10′, is also just visible, but as it can only be faintly traced on three of the negatives, we have thought it best not to give it separately in the catalogue.

B 1. Distinctly visible; the outer arc is also to be seen.
B 2. Quite lost.
B 3. Just traceable.
B 4. Distinctly visible; the outer arc is also to be traced.
B 5. Just visible with a good light.

D 1. Distinctly visible with a good light, though it is cut across by an opaque streak.
D 2. Just visible.
D 3. Distinctly visible; the outer arc is also to be traced.
D 4. Lost.
D 5. Lost.

C δ.—A curving structure, reaching to a height of about $7\frac{1}{2}$′. Its northern edge is markedly concave towards B ϵ, and its summit is pointed, and curves over so as to give an appearance of contrary flecture. Its outline is rather indefinite, and it is not well shown on Plate xi.

B 1. Very distinctly seen; there appears also to be another branch towards the south.
B 2. Quite lost.
B 3. Barely distinguishable.
B 4. Well seen.
B 5. Just visible.

D 1. Only just to be made out; very hazy.
D 2. Very hazy; barely visible.
D 3. Well seen, especially its upper part.
D 4. Lost, or only just visible.
D 5. Quite lost.
D 6. Lost.

C δ_1.—An indefinite cloudy mass, about 11′ high, from which the three rays C α, C β, and C γ appear to spring. Its general axis is inclined from the radial towards the south at an angle of about 10°. Its outline is very indefinite, and it is not well shown on Plate xi.

B 1. Well seen, although a flaw runs across its place.
B 2. Distinctly seen.
B 3. Well seen, but hazy.
B 4. Well seen.
B 5. Well seen, but very hazy.

D 1. Moderately well seen, but interfered with on its northern edge.
D 2. Visible, but woolly.
D 3. Visible; very woolly.
D 4. Traceable; very hazy.
D 5. Lost.

C θ.—A two-branched structure, nearly 4′ high; its stem is inclined from the radial towards the south at an angle of about 20°. Its two branches curl sharply over in opposite directions, and it appears to resemble A θ, on a smaller scale. It can only be made out with a strong transmitted light.

B 1. Distinctly seen.

B 2. Its stem is distinctly seen, but its branches are very hazy.

B 3. Just visible, but very foggy.

B 4. Distinctly seen.

B 5. Its place is occupied by two minute flaws, which make it difficult to recognize anything but its lowest portions.

D 1. Its lower part is quite lost in an opaque mass; possibly its upper part is just traceable; its branches are quite lost.

D 2. Just visible.

D 3. Visible, but very woolly.

D 4. Lost.

D 5. Lost.

C ι.—A slightly curved slender ray, about 15′ high; its general axis has an inclination from the radial towards the south. It is concave towards the south, and its curvature is decidedly greatest in its upper part.

B 1. Well seen, though there is a flaw which just obliterates its summit.

B 2. Quite lost, although there is a foggy, indefinite mass which appears to correspond to the three rays, C ι, C κ, C λ.

B 3. Visible, but very foggy.

B 4. Well seen.

B 5. Easily seen, but foggy.

D 1. Only just visible as a separate ray. Owing to an opaque streak, which seems to take its rise from its summit, it has the appearance of turning over sharply towards the east. The parallelism of the streak to the edge of the plate is best seen by reflected light. On the background of a clear sky the summit of the ray C ι may be distinctly traced as of greater intensity than the rest of the streak.

D 2. Lost as a separate ray.

D 3. Visible, but very woolly.

D 4. Visible, but very hazy; it is cut across by the two concentric lines mentioned in the general description of plate 4.

D 5. Just visible.

J 1. A mass representing C ι, C κ, and C λ, merged in one, is distinctly recognizable.

J 2. The mass visible in J 1 is here only just recognizable.

C κ.—A nearly straight ray, about 20′ high; its northern edge is more definite than its southern; it appears slightly to bend over towards the south. Its general axis is not quite radial, but is slightly inclined towards the south.

B 1. Very well seen, although it is nearly cut through at its summit by a flaw. Its extension is greatest as seen on this negative.

B 2. All but its base is lost.

B 3. Visible, but very foggy.

B 4. Well seen except its summit, which is interfered with by a minute photographic flaw.

B 5. Well seen, but hazy.

D 1. Well seen, though there is a minute dark marking towards its summit, which gives the appearance of a spur branching towards the south; but, as this cannot be traced on any other of the negatives, it is probably due to a photographic flaw.

D 2. Lost as a separate ray.

D 3. Visible as a separate ray.

D 4. Almost lost as a separate ray.

D 5. Almost lost as a separate ray; very hazy.

C λ.—A very faint ray, about 18′ high; it is hardly to be distinguished, except just at its summit, as separate from C κ.

B 1. Scarcely separable from C κ.

B 2. Quite lost.

B 3. Quite merged in C κ.

B 4. Well seen.

5. Well seen, though somewhat hazy.

D 1. Scarcely distinguishable from C κ.

D 2. Quite lost as a separate ray.

D 3. Only just distinguishable.

D 4. Lost.

D 5. Lost.

C μ.—A two-branched structure, nearly 5′ high. Its stem is still more inclined from the radial than that of C θ, and its inclination is also towards the south. Its two branches are about on the same level, the southern one being slightly the larger. They curl over so as to be hook-shaped. Its stem appears to be broader at the base, and double. It is best seen by very strong transmitted light.

B 1. Very well seen in this negative.
B 2. Well seen, but hazy.
B 3. Visible, but hazy.
B 4. Very well seen.
B 5. Well seen.

D 1. Its summit is only just visible above a dense opaque mass.
D 2. Only just visible; very foggy.
D 3. Visible, but very hazy.
D 4. Perhaps just traceable.
D 5. Lost.

C ν.—A pointed, apparently radial, straight ray, about 15′ high, with a strong transmitted light; it may be traced nearly down to the limb, where it appears to spring from behind D β. At a height of 5′ above the limb, it has a breadth of about $3\frac{1}{2}$′. Its outline is isosceles, and its northern edge appears to be more sharply defined than its southern.

B 1. Well seen.
B 2. Seems to be quite lost.
B 3. Visible, but very hazy.
B 4. Well seen.
B 5. Well seen, but very woolly.

D 1. Well seen, but the area between it and C λ is filled by a partially opaque streak, which can be traced in a direction parallel to the edge of the plate for a distance of more than 40′ from the moon's limb.
D 2. Its summit is just visible.
D 3. Visible, but woolly.
D 4. Quite visible; cut across by the concentric streaks.
D 5. Just visible; very hazy.

J 1. Its summit is distinctly traceable.
J 2. Not so well seen as in J 1.

C ξ.—A very faint ray, about 17′ high, apparently springing from behind C ν, and inclined from the radial towards the south.

B 1. Best seen on this negative.
B 2. Quite lost.
B 3. Quite lost.
B 4. Visible, but not well seen.
B 5. Well seen, but very hazy.

D 1. Quite lost.
D 2. Quite lost.
D 3. Lost, or only just traceable
D 4. Possibly just traceable; its place is cut across by two bright concentric streaks.
D 5. Lost.

Plate XIII.

D a.—A faint ray, about 17′ high; clearly separated from C ξ by a narrow rift. It is decidedly inclined from the radial towards the south, so as to be nearly parallel with the axis of the D group.

B 1. Best seen on this negative.
B 2. Quite lost.
B 3. Very foggy; perhaps just seen.
B 4. Well seen.
B 5. Well seen, but slightly hazy.

D 1. Quite lost, owing to a transparent streak. Possibly its upper part may just be seen.
D 2. Lost.
D 3. Faintly visible.
D 4. Lost.
D 5. Lost.

J 1. Lost, or possibly visible as merged with D β and D γ.
J 2. Much as in J 1, though the extension is not so great.

D β.—A remarkably definite narrow ray, which reaches a height of about 16′. It is nearly straight, and inclined from the radial towards the south at an angle of quite 30°, so as to appear parallel to the axis of the D group. It springs from a broad base whose curved outline can be traced nearly down to the moon's limb, and appears to lie in front of the base of C ν. Towards its summit it divides into two slightly spreading and nearly equal branches, which can be traced as slightly convex to one another for a distance of 3′. The southern branch is slightly the longer.

B 1. Best seen in this negative.
B 2. Its spreading lower part is well seen, but its upper portion is quite lost.
B 3. Moderately well seen except at its summit, where there is a flaw at the place where the ray branches.
B 4. Well seen, though woolly at its summit.
B 5. Well seen.

D 1. Moderately well seen, though its swelling base and the branches at its summit are lost.
D 2. Visible, but very woolly; its base and summit are lost.
D 3. Moderately well seen, though woolly; its branching summit is lost.
D 4. Just visible, but very woolly; its summit is quite lost.
D 5. Its base is visible.

J 1. Only just visible as distinct from D γ; its base and summit are quite lost.
J 2. It is more distinctly separated from D γ than in J 1.

D γ.—A slightly curved ray, which reaches a height of 22′. It is nearly parallel to D β, and springs from a somewhat similar swelling base. Its southern edge is much the most definite, except towards the summit, where its northern edge is more distinct. At a height of about 9′ it is crossed by D δ, which can be distinctly traced either through or upon it.

B 1. Very well seen on this negative.
B 2. Only its base is visible.
B 3. Moderately well seen, though hazy.
B 4. Very well seen, though it is apparently separated into two parallel rays in its upper parts, which cannot be traced in the other negatives.
B 5. Very well seen.

D 1. Its base is lost, but its upper parts are well seen.
D 2. Very woolly; its base and summit are both lost.
D 3. Very woolly; its base is quite lost.
D 4. Traceable, but woolly; the southern edge of its base is moderately well seen.
D 5. Its base is moderately well seen.

J 1. Scarcely visible as a separate ray.
J 2. The extension is not so great as in J 1.

D δ.—A slightly curved ray, about 12½′ high. It is decidedly inclined from the radial towards the east, and at a height of about 9′ it crosses D γ, and can be traced as far as the southern branch of D β.

B 1. Well seen in this negative.
B 2. Only the base can be seen; it is distinctly recognizable as double.
B 3. Visible, though hazy.
B 4. Moderately well seen, but very opaque at its base.
B 5. Moderately well seen, though very hazy.

D 1. Visible, but very hazy, and opaque at the base.
D 2. Visible, but very woolly.
D 3. Visible, very woolly.
D 4. Visible, but foggy.
D 5. Distinctly visible, though hazy.

J 1. Traceable just below where it crosses D γ.
J 2. Just traceable, though not so well seen as in J 1.

D ϵ.—A very faint ray, about 19′ high; it appears to be nearly parallel to the upper part of D γ, and is consequently inclined from the radial towards the south.

B 1. Well, perhaps best, seen in this negative.
B 2. Lost.
B 3. Lost, probably in consequence of a dense oblique marking parallel to the edge of F δ.
B 4. Well seen.
B 5. Just distinguishable.

D 1. Barely distinguishable.
D 2. Lost.
D 3. Lost as a separate ray.
D 4. Lost as a separate ray.
D 5. Lost.

D ζ.—A very faint ray, about 18′ high. It is somewhat narrower than D ϵ, but nearly parallel to it, and of about the same intensity.

B 1. Well seen.
B 2. Lost.
B 3. Lost as a separate ray.
B 4. Moderately well seen.
B 5. Well seen, though hazy.

D 1. Quite visible, though foggy.
D 2. Lost.
D 3. Lost as a separate ray.
D 4. Lost as a separate ray.
D 5. Lost.

D η.—A triangular mass, about 9′ high; its eastern edge is pretty sharply defined above the point where it crosses D δ, but its western edge is very indefinite.

B 1. Well seen.
B 2. Its eastern edge is visible.
B 3. Visible, but hazy.
B 4. Well seen.
B 5. Visible, but very hazy.

D 1. Well seen.
D 2. Its eastern edge is visible just above where it crosses B δ.
D 3. Traceable, but woolly.
D 4. Traceable, but very woolly.
D 5. Its eastern edge, just above where it crosses B δ, is just visible.

J 1. Just traceable.
J 2. Lost.

D θ.—A very faint triangular mass, whose delicate pointed summit can be traced to a height of 19′. At a height of about 14′ it is crossed by the upper part of D ν, which gives the appearance of another triangular mass of greater intensity within D θ.

B 1. Well seen.
B 2. Lost.
B 3. Just visible, though its summit is lost.
B 4. Well seen.
B 5. Well seen, especially its eastern edge.

D 1. Just traceable.
D 2. Lost.
D 3. Just traceable.
D 4. Lost, though perhaps the lower part of its eastern edge is traceable.
D 5. Lost.

D ι.—A nearly opaque mass, or small ray, about 3′ high; its pointed summit curves towards the west so as to be nearly horizontal. It appears to spring from a broad spreading base, and its axis of symmetry is very decidedly inclined from the radial towards the west.

B 1. Well seen.
B 2. Moderately well seen, but faint.
B 3. Lost.
B 4. Well seen, though not so sharp as in B 1.
B 5. Only its base is visible.

D 1. Just traceable.
D 2. Quite visible.
D 3. Just traceable.
D 4. Lost.
D 5. Lost.

D κ.—A very small curving ray, which bends over in the direction of D ι. It is only about $1\frac{1}{2}'$ in height.

B 1. Well seen on this negative, though it appears to be divided into two.
B 2. Only just visible; very faint.
B 3. Lost.
B 4. Moderately well seen.
B 5. Just visible.

D 1. Lost.
D 2. Lost.
D 3. Lost.
D 4. Lost.
D 5. Lost.

D λ.—A curved ray, which reaches a height of about $4\frac{1}{2}'$. At the height of $2'$ it appears to split into two branches, the more easterly one of which curves over until it nearly touches D ι. Both of the branches are concave towards the axis of the D group.

B 1. Well seen.
B 2. Moderately well seen.
B 3. Only just traceable.
B 4. Moderately well seen.
B 5. Just traceable; very hazy.

D 1. Traceable.
D 2. Lost.
D 3. Lost, or only just traceable.
D 4. Lost.
D 5. Lost.

D μ.—A curved ray, about $6\frac{1}{2}'$ high; it is concave towards the axis of the D group, and evidently similar in character to the details D λ and D ν. It appears to be forked at its summit.

B 1. Well seen.
B 2. Just visible.
B 3. Lost.
B 4. Moderately well seen.
B 5. Visible, though hazy; its summit is interfered with by an opaque flaw.

D 1. Visible, though woolly.
D 2. Lost.
D 3. Only just traceable; exceedingly woolly.
D 4. Lost.
D 5. Lost.

D ν.—A remarkable curving structure, which reaches to a height of $13'$. It is concave towards the axis of the D group, and its curvature is decidedly greater towards its summit. The general direction of its stem is markedly inclined from the radial towards the east. At a height of about $8'$ it splits up into two branches, and both of these branches appear to be double towards their extremities. The whole of its summit is, however, very hazy.

B 1. Well seen.
B 2. Lost.
B 3. Visible, though very hazy; the branching character of its summit is quite lost.
B 4. Moderately well seen.
B 5. Visible, though very hazy.

D 1. Visible as a curving nebulous mass.
D 2. Lost.
D 3. Visible as a curving nebulous mass; its branched character is only just traceable.
D 4. Lost, or possibly just traceable.
D 5. Quite lost as a separate ray, though its curved southern edge is distinctly seen forming the edge of the great southern rift, D ζ being quite lost.

D ξ.—A triangular mass, with a delicate pointed summit, which reaches to a height of $19'$. It appears to be of the same character as D θ, though much more opaque.

B 1. Well seen.
B 2. Lost.
B 3. Visible, but hazy.
B 4. Well seen.
B 5. Well seen, though hazy.

D 1. Well seen.
D 2. Part of its southern edge is just traceable.
D 3. Moderately well seen.
D 4. Traceable, but very hazy.
D 5. Lost.

D *o*.—A curving ray, which forms the eastern boundary of the great southern rift. Its western edge shows a very marked double curvature, and its eastern edge, though less definite than its western, is distinctly concave towards the axis of the D group. Its general axis of symmetry is very decidedly inclined from the radial towards the east. At a height of $6'$, on the side next the rift, is a delicate spur, which appears again to merge with the main stem at a height of about $10'$.

B 1. Well seen; the spur is particularly well seen on this negative.
B 2. The upper part and the spur are quite lost.
B 3. Visible, but hazy. The spur is, however, distinctly to be traced.
B 4. Moderately well seen.
B 5. Moderately well seen.

D 1. Moderately well seen, though woolly; the spur can only just be traced.
D 2. Very woolly; its upper part is interfered with by a streak; the spur is quite lost.
D 3. Very woolly; the spur is quite lost.
D 4. Lost as a separate detail.
D 5. Quite lost as a separate detail.

J 1. Not visible as a separate ray, but the curvature of its western edge is well marked.
J 2. Not so much extension as in J 1.

Plate XIV.

E *α*.—An opaque mass, about $3'$ high; its general axis is inclined from the radial towards the west at an angle of quite 40°.

B 1. Well seen.
B 2. Well seen.
B 3. Well seen.
B 4. Very opaque, but visible.
B 5. Well seen.

D 1. Its summit is visible, but its stem is lost in the general opacity.
D 2. Just traceable.
D 3. Only just traceable.
D 4. Lost.
D 5. Lost.

J 1. Lost.
J 2. Its summit is quite visible

E *β*.—A delicate double ray, which appears to spring from behind E *α*. Its two slightly diverging branches reach to a height of about $5'$.

B 1. Best seen in this negative.
B 2. Lost.
B 3. Visible; merged together.
B 4. Well seen.
B 5. Lost.

D 1. Lost.
D 2. Lost.
D 3. Lost.
D 4. Lost.
D 5. Lost.

E *γ*.—A nebulous ray, which can be traced to a height of $13'$. For some little distance above the summit of E *α* it appears double. Its general axis is slightly inclined from the radial towards the east, and is remarkably parallel to E *δ* and E *β*.

B 1. Well seen.
B 2. Its lower part is traceable, but not as double.
B 3. Very hazy; the two rays are merged into one.
B 4. Well seen. Just above G α it appears to be divided into three rays.
B 5. Visible, but very woolly. It is interfered with by a photographic flaw at a height of about 6′.

D 1. Visible as a single nebulous ray, distinctly separate from G δ.
D 2. Lost on its lower part; is just visible as separate from G δ.
D 3. Lost as a separate ray.
D 4. Lost.
D 5. Lost.

E δ.—A very definite, slender ray, reaching to a height of about 16′; it is inclined from the radial at an angle of about 10° towards the east. Its edges are remarkably sharp, except within a few minutes of its summit, where it becomes somewhat nebulous, more especially on its western side. It appears to spring from a swelling base, somewhat like that of D β.

B 1. Well seen.
B 2. Only visible to a height of about 5′.
B 3. Visible, but very hazy.
B 4. Well seen.
B 5. Well seen, but rather hazy.

D 1. Visible, but hazy.
D 2. Traceable to a height of about 10′.
D 3. Lost, or only just traceable.
D 4. Lost.
D 5. Lost.

E ϵ.—A broad and rather spreading ray, which can be traced by reflected light to a height of 19′. Its edges appear decidedly darker than its central portions, and they might almost be regarded as separate rays. Both of them are slightly curved, so as to be concave, towards the F group; but the curvature of the western edge is the most marked.

B 1. Well seen.
B 2. Only the lower portions of the two dark edges are visible.
B 3. Just visible; very hazy.
B 4. Well seen.
B 5. Well seen, though rather hazy.

D 1. Moderately well seen, though woolly.
D 2. Only its lower part is visible.
D 3. Visible, but very woolly.
D 4. Lost as a separate ray.
D 5. Lost.

J 1. Not visible as a separate ray.
J 2. The division between it and the H group is distinctly traceable.

Plate XV.

F α.—A curved ray, which forms the eastern edge of the F group. It is concave towards the axis of the F group. To a height of about 10′ its general direction is radial; it then begins rather suddenly to curve away towards the west. At its base it appears to be about 3′ broad; but its western edge is very indefinite, and cannot be traced above a height of about 9′. At a height of about 4′ is a spur, which has the appearance of being a structure, similar to H β, or H γ.

B 1. Well seen.
B 2. Only its broad base is visible.
B 3. Visible, but hazy.
B 4. Well seen.
B 5. Well seen.

D 1. Just visible as a separate ray.
D 2. Possibly just visible.
D 3. Just visible as a separate ray.
D 4. Lost, or only just visible.
D 5. Lost.

F β.—A very faint branching structure, which extends to a height of about 10′. Its stem is very indistinct, and it is difficult to determine its outline with certainty; but it appears to be slightly concave towards the axis of the F group, and to be inclined from the radial towards the east. The two branches do not curve away from one another as in the branching structures of the B group, but are inclined to one another at an angle of about 45°, and are slightly concave to each other.

B 1. Very well seen.
B 2. Its lower part is traceable.
B 3. Traceable, but very hazy.
B 4. Well seen, though it is cut across by a streak.
B 5. Moderately well seen, but hazy.

D 1. Quite visible, but very woolly.
D 2. Its lower part and eastern branch is visible, but it is cut across by streaks above.
D 3. Distinctly visible, though woolly.
D 4. Possibly just traceable.
D 5. Lost.

F γ.—A faint branching structure, very similar to F β. It also extends to a height of about 10′. But its stem is nearly radial, and is somewhat thicker than the stem of F β.

B 1. Well seen.
B 2. Its lower part is moderately well seen.
B 3. Quite visible, but hazy.
B 4. Well seen, but its western branch is much interfered with by an opaque streak.
B 5. Moderately well seen, except the western branch, which is scarcely traceable.

D 1. Its stem is very opaque and distinctly seen, but its branches are almost lost.
D 2. Its stem is visible as a broad dark mass, but its summit is interfered with by streaks.
D 3. Its branches seem quite lost, but its stem is visible as a dark mass.
D 4. Just traceable.
D 5. Possibly just traceable.

F δ.—A very small curving ray, not quite 3′ high. Its general axis is inclined from the radial towards the south, and it is concave towards the axis of the F group. It appears broad at its base, and is probably double, there being a still smaller curving ray to the south of it.

B 1. Well seen.
B 2. Visible.
B 3. Just traceable.
B 4. Well seen, but opaque.
B 5. Traceable, though woolly.

D 1. Quite lost, by reason of a remarkable black flaw.
D 2. Quite traceable.
D 3. Just traceable.
D 4. Lost as a separate ray.
D 5. Lost as a separate ray, though a mass representing δ, ϵ, ζ is clearly seen.

F ϵ.—A curving ray, nearly 4′ high. It is concave towards the axis of the F group, and is inclined from the radial towards the south. It is somewhat nebulous at its summit, and seems intimately connected with F δ and F ζ.

B 1. Well seen.
B 2. Visible, though very faint.
B 3. Visible, but very hazy.
B 4. Very well seen.
B 5. Visible, though hazy.

D 1. Just distinguishable as a separate ray.
D 2. Quite visible.
D 3. Traceable, but very woolly.
D 4. Lost as a separate ray.
D 5. Quite lost as a separate ray.

F ζ.—A curving ray, forked at its summit, nearly 7′ high; concave towards the axis of the F group, and decidedly inclined from the radial towards the south.

B 1. Well seen.
B 2. Well seen, but faint.
B 3. Well seen, though hazy.
B 4. Well seen.
B 5. Well seen, though hazy.

D 1. Barely visible as a separate ray; its forked summit is, however, traceable.
D 2. Moderately well seen, though woolly.
D 3. Its forked summit is visible, but below it is barely traceable as a separate ray.
D 4. Lost as a separate ray.
D 5. Quite lost as a separate ray.

J 1. Its western edge is quite traceable, and also part of the contour of the mass formed of δ, ϵ, and ζ, merged into one.
J 2. Rather better seen than in J 1; it is, however, not visible as a separate ray.

F η.—A curving ray, which reaches a height of more than 15′. It is concave towards the axis of the F group, and curves over much more rapidly towards its summit. Its general direction is decidedly inclined from the radial towards the south. At a height of about 8′ a delicate straight spur branches off from its western edge, and reaches a height of nearly 12′. Above the spur it becomes nebulous on both its eastern and western edges; but a delicate curving stem can be traced through it, which branches towards its summit.

B 1. Very well seen.
B 2. Distinctly visible to a height of about 8′.
B 3. Very hazy; towards the summit the spur is lost.
B 4. Moderately well seen.
B 5. Moderately well seen, though hazy.

D 1. Visible, though very woolly.
D 2. Its summit is completely lost.
D 3. Moderately well seen, though hazy; its forked summit is lost.
D 4. Its general outline is visible, though very hazy.
D 5. The outline of its lower part is traceable.

J 1. Its general outline is quite traceable, though the forked summit is of course lost.
J 2. Its lower part is recognizable, though it is not so well seen as in J 1.

F θ.—A nebulous field, which envelopes all the details of the F group except ι. By reflected light it can be traced to a height of quite 26′. Its greatest extension is at the centre of the group; on either side it falls off pretty symmetrically, and very rapidly.

B 1. Very well seen.
B 2. Lost, or only quite its lower part is visible.
B 3. Owing to the fogging of the plate its outline cannot be traced, but it evidently has considerable extension.
B 4. Well seen.
B 5. Well seen, though the background is hazy.

D 1. Well seen, but cut off very abruptly above.
D 2. Interfered with by photographic flaws.
D 3. Well seen.
D 4. Moderately well seen.
D 5. Its extension is very small, about 15′ at most.

J 1. Moderately well seen; it has an extension of more than 15′.
J 2. Not so well seen as in J 1.

F ι.—A straight, nearly radial ray, about 20′ high. Its eastern edge seems the more sharply defined, though this is possibly by contrast with the narrow rift which separates it from G α, which can be traced to within 8′ of the same limb.

B 1. Well seen.
B 2. Its lower part is visible.
B 3. Traceable, though very hazy.
B 4. Well seen.
B 5. Well seen, though rather hazy.

D 1. Quite visible, though woolly; rather abruptly cut off at its summit.
D 2. Only just traceable.
D 3. Moderately well seen, though woolly.
D 4. Just traceable.
D 5. Lost.

J 1. Lost.
J 2. Lost.

PLATE XVI.

G α.—A nearly straight, double, pointed ray, which reaches a height of about 21′. It is not quite radial, but inclined a few degrees towards the south. It has the appearance of being composed of two rays, the northern one of which is narrow and divides into two delicate and slightly divergent branches at a height of about 15′. The southern ray is broader and fainter, and its axis is slightly inclined towards the axis of the northern forked ray.

B 1. Very well seen.
B 2. Lost.
B 3. Lost, though the southern edge is traceable.
B 4. Well seen.
B 5. Well seen, though hazy.

D 1. Quite visible; but very woolly in its lower parts, and faint above.
D 2. Lost.
D 3. Visible, but its summit is almost lost.
D 4. Its lower parts are just traceable; above, it is interfered with by a flaw.
D 5. Lost.

J 1. Just visible; its southern edge is moderately distinct in contrast with the rift.
J 2. Lost.

G β.—A very faint, apparently straight ray, which reaches a height of 22′. Its general direction is parallel to α, and it is therefore distinctly inclined from the radial towards the south. It is only traceable as a separate ray above where it crosses γ.

B 1. Well seen.
B 2. Lost.
B 3. Lost.
B 4. Well seen, though very faint.
B 5. Well seen, though rather hazy.

D 1. Its upper part is visible; below it is cut across by a streak.
D 2. Lost.
D 3. Just traceable.
D 4. Lost. D 5. Lost.

G γ.—A nebulous, broad ray, whose axis is inclined from the radial towards the north. It extends to a height of more than 21′. Its southern edge is more marked than its northern, and can be traced down as far as the lower part of F η. On the north it is separated from the southern branch of δ by a narrow rift.

B 1. Well seen.
B 2. All but the lower part of its northern edge is lost.
B 3. Lost.
B 4. Well seen; its northern edge is very soft.
B 5. Moderately well seen, though hazy.

D 1. Its place is cut across by a transparent rift, which makes it difficult to recognize it.
D 2. Lost.
D 3. Quite traceable, as in B 4 and B 5; its northern edge is very soft.
D 4. Lost. D 5. Lost.

G δ.—A forked ray, partly superposed upon G γ. Its southern branch is nearly in the

same straight line with its main stem, and is slightly inclined from the radial towards the south. Its southern branch springs from the main stem at a height of about 11′, and is inclined at an angle of about 30° to the northern branch. The whole reaches a height of about 20′, and is only seen with difficulty.

B 1. Moderately well seen, but faint.
B 2. Only its lower part can be made out.
B 3. Lost.
B 4. Well seen.
B 5. Moderately well seen

D 1. Lost.
D 2. Lost.
D 3. Moderately well seen, though its southern branch appears double.
D 4. Its stem and northern branch are distinctly visible.
D 5. Its stem is distinctly traceable.

G ϵ.—A narrow, nearly straight ray, which extends to a height of about 19′. It is inclined from the radial about 10′ towards the north. At a height of about 14′ it appears to give off a somewhat thick and cloudy spur towards the north. To the south it is separated from the northern branch of δ by a narrow rift.

B 1. Well seen.
B 2. Its lower parts are moderately well seen.
B 3. Only its base is visible.
B 4. Very well seen.
B 5. Visible, though somewhat hazy.

D 1. Moderately well seen.
D 2. Moderately well seen, though woolly.
D 3. Moderately well seen.
D 4. Well seen, though rather hazy.
D 5. Visible, though very hazy.

J 1. G ϵ, η, and ξ are seen merged together, as into a conical mass.
J 2. The mass visible in J 1 is distinctly seen to be divided into three.

G ζ.—A nearly straight, broad, and rather opaque ray, which reaches to a height of about 13′. At a height of about 8′ it divides into branches, which diverge from one another at an angle of about 20°; the two branches are, however, very indefinite.

B 1. Well seen.
B 2. Its base is only just distinguishable as much fainter than the bases of η and ϵ.
B 3. Just visible, though very faint.
B 4. Well seen.
B 5. Visible, though very hazy; the northern branch is lost.

D 1. Lost, or possibly just traceable.
D 2. Visible, though very woolly.
D 3. Traceable, though very woolly; the branches are lost.
D 4. Visible, though hazy.
D 5. Distinctly traceable.

J 1. Not visible as a separate ray.
J 2. Distinctly visible as a separate ray; possibly its forked summit may be traced.

G η.—A somewhat opaque, nearly radial ray, which extends to a height of about 12′. On its southern edge, extending to a height of 3′ or 4′, is a small spur, concave towards the south.

B 1. Well seen.
B 2. Its lower part and the spur are well seen.
B 3. Its lower part and the spur are just visible.
B 4. Well seen, though rather opaque at its base.
B 5. Its base and the spur are just distinguishable; but owing to the streaks caused by the movement of the instrument, its upper part is quite lost.

D 1. Visible, though very woolly.
D 2. Visible, but very woolly.
D 3. Moderately well seen, though woolly.
D 4. Visible, though very hazy.
D 5. Its lower part is visible, though very foggy; the spur is quite lost.

G θ.—A very faint ray, which reaches a height of quite 26′. Only its upper part is visible, but it has the appearance of being a straight and very nearly radial ray.

B 1. Very well seen.
B 2. Lost.
B 3. Lost.
B 4. Moderately well seen.
B 5. Moderately well seen.

D 1. Moderately well seen, though it is cut across just above γ by an oblique channel.
D 2. Lost.
D 3. Traceable; merged with β.
D 4. Lost.
D 5. Lost.

G ι.—A faint ray, which extends to a height of about 20′. Only its summit above ϵ and ζ is visible. Its northern edge is pretty sharply defined, and considerably inclined from the radial towards the south.

B 1. Well seen.
B 2. Lost.
B 3. Lost.
B 4. Moderately well seen.
B 5. Lost, or only just visible.

D 1. Lost.
D 2. Lost, or only just traceable.
D 3. Apparently cut across towards the south by a bright channel.
D 4. Lost, or only partly traceable.
D 5. Lost.

G κ.—A faint ray, which extends to a height of about 20′. It is of about the same intensity as ι. Only its summit is visible; its southern edge is pretty sharply defined, and is considerably inclined from the radial towards the north. Its northern edge is sharply defined and nearly radial.

B 1. Very well seen.
B 2. Lost.
B 3. Lost.
B 4. Well seen.
B 5. Lost, owing to the slipping of the plate.

D 1. Lost.
D 2. Lost, or possibly traceable.
D 3. Moderately well seen.
D 4. Lost.
D 5. Lost.

G λ.—A long straight ray, reaching to a height of about 20′. It is but slightly inclined from the radial towards the south. Its southern edge is most marked near its base, and between it and η there is a faint spur, reaching to a height of 7′.

B 1. Well seen.
B 2. Its upper part is lost, but its base and the spur are well seen.
B 3. Its lower part is just traceable.
B 4. Well seen.
B 5. Lost.

D 1. Well seen, though somewhat woolly.
D 2. Its upper part is lost; the spur is only just distinguishable.
D 3. Visible, though very woolly.
D 4. Visible, though very hazy.
D 5. Its lower part is visible, though very hazy; the spur is lost.

J 1. An opaque mass, evidently composed of λ, μ, and ν merged in one; is distinctly recognizable, and possibly λ is just distinguishable as a separate ray.
J 2. The mass representing λ, μ, and ν is distinctly visible.

G μ.—A straight and rather slender ray, which can be traced to a height of 22′. It has the appearance of springing from the same base as λ. Below a height of 10′ it appears merged with λ, so that only its northern edge can be distinguished.

B 1. Well seen.
B 2. Lost, or possibly its base is seen merged with λ.
B 3. Lost.
B 4. Lost, or only just visible, in consequence of an opaque streak.
B 5. Lost.

D 1. Visible; merged with λ.
D 2. Lost.
D 3. Moderately well seen.
D 4. Scarcely visible as separate from λ.
D 5. Visible; merged with λ.

J 1. Possibly just distinguishable as separate rom λ and ν.
J 2. Merged with λ and ν.

G ν.—A long straight ray, reaching to a height of quite $25'$. It is decidedly inclined from the radial towards the south. It is separated from μ by a gap which is broadest below. At a height of about $13'$ it is lost in a triangular-shaped opaque mass, which also covers the lower parts of μ and λ. It is decidedly inclined away from σ and towards μ. Its base cannot be distinctly traced, but it probably springs from π, or near to π.

B 1. Very well seen.
B 2. Its lower part is visible.
B 3. Lost.
B 4. Well seen.
B 5. Lost, owing to the slipping of the plate.

D 1. Moderately well seen.
D 2. Lost above where it crosses ξ, though visible just below.
D 3. Visible below where it crosses ξ.
D 4. Its lower part is visible, but very hazy.
D 5. Lost, or only just traceable.

J 1. Just distinguishable as a separate ray.
J 2. Only traceable as merged with the lower parts of λ, μ, and ν.

G ξ.—A long ray, very markedly inclined from the radial towards the north. It can be traced to a height of $22'$. Above where it crosses ν its southern edge is pretty definitely marked, though it is decidedly fainter than ν. It has the appearance of springing from a point to the south of the base of η. It is not well shown in Plate xvi.

B 1. Well seen.
B 2. Lost.
B 3. Lost.
B 4. Moderately well seen.
B 5. Lost, owing to the slipping of the plate.

D 1. Moderately well seen.
D 2. Lost above where it crosses ν.
D 3. Lost, or only just visible above where it crosses ν.
D 4. Its southern edge below, where it crosses ν, is visible.
D 5. Lost.

J 1. Its southern edge, below where it crosses ν, is distinctly visible.
J 2. Not quite so well seen as in J 1.

G o.—A small curving mass, which reaches a height of about $3'$. It has a broad base and a pointed summit, which curves over rather sharply towards the south.

B 1. Well seen. Its summit has the appearance of being double, with two branches curving over in opposite directions.
B 2. Well seen.
B 3. Lost.
B 4. Well seen.
B 5. Lost.

D 1. Moderately well seen.
D 2. Moderately well seen.
D 3. Well seen.
D 4. Just traceable.
D 5. Lost.

G π.—A small curving mass, or ray, very similar in form to o; it reaches a height of about 4′; it appears to be divided into two masses, each concave towards the south.

B 1. Well seen.
B 2. Well seen.
B 3. Visible, though very hazy.
B 4. Distinctly visible, though very opaque.
B 5. Lost.

D 1. Visible, but very woolly.
D 2. Visible, but extremely woolly.
D 3. Quite visible, though woolly.
D 4. Traceable, though very hazy.
D 5. Recognizable, though extremely hazy.

G ρ.—A curving ray, concave towards the south, which reaches to a height of about 3½′. It is slender compared with π and o, and has a delicate spur springing from its base and curving over towards the south, so as nearly to connect it with π.

B 1. Well seen.
B 2. Distinctly visible, though very faint.
B 3. Just traceable; very hazy.
B 4. Well seen, though rather opaque.
B 5. Lost.

D 1. Moderately well seen.
D 2. Just visible.
D 3. Moderately well seen.
D 4. Just traceable, though very hazy.
D 5. Lost.

G σ.—A very slender and apparently straight ray, which reaches to a height of about 17′. It can be traced down to near the summit of ρ, and appears inclined from the radial towards the south at an angle of about 10°.

B 1. Well seen.
B 2. Lost.
B 3. Lost.
B 4. Quite visible, though not well seen.
B 5. Lost.

D 1. Quite visible.
D 2. Lost, or only just traceable.
D 3. Moderately well seen.
D 4. Only just traceable.
D 5. Lost.

G τ.—A long and apparently straight ray, which appears nearly radial. It reaches to a height of quite 22′. Its southern edge is the most sharply defined, but it is distinctly separated on the north from v, to which it is nearly parallel.

B 1. Very well seen.
B 2. Not visible as a separate ray.
B 3. Lost, or only just distinguishable as a separate ray.
B 4. Well seen.
B 5. Its upper part is visible.

D 1. Moderately well seen, though woolly.
D 2. Its lower part is just visible.
D 3. Distinctly visible, though hazy.
D 4. Lost as a separate ray.
D 5. Lost.

J 1. A mass, evidently representing τ and v merged together, is distinctly traceable.
J 2. Not so well seen as in J 1.

G v.—A long and apparently straight ray, which forms the southern boundary of a narrow rift, which can be traced nearly down to the moon's limb. It reaches to a height of more than 22′, and appears to be quite radial. Its northern edge is the more sharply defined.

B 1. Well seen.
B 2. Not visible as a separate ray.
B 3. Just distinguishable as a separate ray.
B 4. Well seen.
B 5. Moderately well seen, though hazy.

D 1. Quite distinguishable, though woolly.
D 2. Visible, though interfered with by a transparent streak.
D 3. Moderately well seen.
D 4. Lost as a separate ray.
D 5. Lost; only the lower part of its northern edge is visible.

J 1. Not distinguishable as separate from τ.
J 2. Not so well made out as in J 1.

PLATE XVII.

H α.—A delicate, apparently straight ray, forming the northern boundary of the narrow rift which separates the G from the H group. It appears to be radial, and is distinctly traceable to a height of 14′.

B 1. Well seen.
B 2. Quite lost as a separate ray; its southern edge is perhaps traceable.
B 3. Quite traceable, though hazy.
B 4. Well seen.
B 5. Quite traceable, though very hazy.

D 1. Lost, or only just distinguishable as a separate ray.
D 2. Just traceable; very hazy.
D 3. Quite traceable, though hazy.
D 4. Lost as a separate ray.
D 5. Lost.

J 1. Lost as a separate ray, though its southern edge is distinctly visible.
J 2. Only its southern edge is traceable.

H β.—An apparently straight ray, reaching to a height of about 14′. It is slightly inclined from the radial towards the north. To a height of 10′ it is comparatively slender and definite; above that height it spreads out and becomes decidedly nebulous. On its northern edge, at a height of about 6′, is a nebulous excrescence, or spur, which reaches to a height of 9′; a much fainter spur can also be traced on its southern edge a little below the northern one.

B 1. Well seen.
B 2. Lost.
B 3. Visible, though very hazy. The northern and southern spurs are lost, or are only just traceable.
B 4. Very well seen.
B 5. Moderately well seen, though hazy; the northern spur is quite lost.

D 1. Moderately well seen, though its summit is lost.
D 2. From a height of 5′ to 10′ it is well seen.
D 3. Moderately well seen, though woolly.
D 4. Its upper part is traceable, though the spurs are lost.
D 5. Lost.

H γ.—A very faint ray, with two branches or spurs. It can be traced to a height of quite 15′. Its main axis is inclined from the radial towards the north at an angle of more than 30°. It is decidedly concave towards the axis of the H group. At a height of about 9′ is a nebulous spur on its northern edge, and a second spur or branch can also be traced springing from its northern edge at a height of about 10½′, and reaching a height of quite 15′.

B 1. Well seen.
B 2. Lost.
B 3. Only just traceable; very hazy.
B 4. Well seen.
B 5. Quite visible, though hazy.

D 1. Visible, though woolly up to a height of 12′. Its upper spur is cut out by a transparent channel.
D 2. Lost.
D 3. Perhaps just traceable, though very nebulous.
D 4. Lost. D 5. Lost.

H δ.—A slightly curving ray, or possibly a branch springing from the northern side of γ. It is very considerably inclined to the radial, and slightly concave towards the axis of the H group. It can possibly be traced to a height of 13′, but on none of the negatives is it a very marked detail.

B 1. Moderately well seen.	D 1. Only just traceable.
B 2. Its lower part, at a height of 5′ or 6′, is visible.	D 2. Its lower part is traceable.
B 3. Just visible.	D 3. Only just traceable.
B 4. Well seen.	D 4. Lost.
B 5. Visible, though hazy.	D 5. Lost.

H ϵ.—A branched structure, reaching to a height of about 9′. It is decidedly inclined from the radial towards the north. Its main stem is nearly straight, or but slightly concave towards the axis of the H group. At its summit it divides into two apparently equal branches, which curl over symmetrically in opposite directions. It is by no means a conspicuous detail.

B 1. Well seen.	D 1. Lost.
B 2. Just visible.	D 2. Lost.
B 3. Only just traceable.	D 3. Its upper part just traceable.
B 4. Well seen.	D 4. Just to be traced; very hazy.
B 5. Quite visible, though hazy.	D 5. Quite lost.

ζ.—A curving ray, which reaches to a height of about 6′. It is concave towards the axis of the H group, and so curved that its upper portion is almost parallel to the moon's limb. Its lower part cannot be distinctly made out, but it appears to be broad and somewhat nebulous.

B 1. Well seen.	D 1. Lost.
B 2. Moderately well seen.	D 2. Traceable.
B 3. Just visible.	D 3. Its upper part is visible.
B 4. Very well seen.	D 4. Lost, or possibly just traceable.
B 5. Moderately well seen.	D 5. Lost.

H η.—A smaller curving ray, concave towards the north, which reaches to a height of about 3′. At its base, on its northern side, is an opaque mass, which reaches to a height of about $1\frac{1}{2}$′.

B 1. Well seen.	D 1. Lost, or possibly just traceable.
B 2. Moderately well seen, though exceedingly faint.	D 2. Just traceable.
B 3. Just visible; very hazy.	D 3. Lost.
B 4. Moderately well seen.	D 4. Lost.
B 5. Quite visible, though hazy.	D 5. Lost.

H θ.—A curving ray, concave towards the south. It reaches a height of about 4′. Near its base, on its southern edge, a small curving spur can be traced.

B 1. Well seen.	D 1. Only just to be made out; very woolly.
B 2. Moderately well seen.	D 2. Quite visible, though very woolly.
B 3. Visible, though very hazy.	D 3. Quite visible.
B 4. Well seen.	D 4. Just visible.
B 5. Moderately well seen.	D 5. Lost.

H ι.—Apparently the summit of a branching structure, of the same type, though much larger than ϵ. Its stem cannot be traced below ζ. Its southern branch extends to a greater height than its northern by about half a minute. The extreme height of the southern branch is about $9'$.

B 1. Well seen.
B 2. Lost.
B 3. Just visible; very hazy.
B 4. Very well, probably best seen on this negative.
B 5. Visible, though hazy.

D 1. Lost.
D 2. Moderately well seen.
D 3. Quite visible, though very hazy.
D 4. Lost.
D 5. Lost.

H κ.—A delicate curving ray, concave towards the south, which can be traced to a height of $5\frac{1}{2}'$. At its summit it turns over so as to become almost horizontal.

B 1. Moderately well seen, but very faint.
B 2. Only traceable near its base.
B 3. Moderately well seen, though rather faint.
B 4. Very well seen.
B 5. Only its lower part is visible.

D 1. Lost, or only just traceable.
D 2. Distinctly visible, though nearly merged with λ.
D 3. Only just traceable; very woolly.
D 4. Lost.
D 5. Lost.

H λ.—A delicate curving ray, concave towards the south. It springs from the same base as κ, and can be traced to a height of about $6\frac{1}{2}'$.

B 1. Moderately well seen, though very faint.
B 2. Lost.
B 3. Moderately well seen, though rather faint.
B 4. Well seen.
B 5. Only visible as merged with κ.

D 1. Only just traceable.
D 2. Distinctly traceable, though partly merged with κ.
D 3. Its upper part is just traceable, though woolly.
D 4. Lost.
D 5. Lost.

H μ.—A very marked curving ray, concave towards the axis of the H group. To a height of $5'$ it is comparatively slender, and its general direction is radial; above that height it becomes broader and curves over rapidly towards the west. Its northern edge is very well marked, owing to the transparent rift which separates it from ν, and can be traced to a height of $10'$. Its western edge is less marked, but can be distinctly seen curving over into a branch or spur, immediately below the northern branch of ι. Above ι its western edge appears entirely lost.

B 1. Well seen.
B 2. Lost above a height of $8'$.
B 3. Moderately well seen, though hazy.
B 4. Very well seen.
B 5. Moderately well seen, though hazy.

D 1. Its northern edge is well marked, but the western edge is lost.
D 2. Moderately well seen, though woolly.
D 3. Visible, though very woolly.
D 4. Visible, but very hazy.
D 5. All but its northern edge is lost.

J 1. The upper part of its northern edge is distinctly to be traced.
J 2. Its northern edge is decidedly sharper than in J 1; possibly a portion of its western edge can also be made out.

H ν.—A curved ray, concave towards the axis of the H group. It is very nebulous, but can be traced to a height of quite $14'$. At its base, between it and μ, there is a very

minute ray, or spur, which can be traced to a height of at least 5′. On its western edge, at a height of about 9′, another small spur can be traced.

B 1. Well seen.
B 2. Moderately well seen to a height of 7′.
B 3. Quite visible, though very hazy, and interfered with by an opaque photographic flaw.
B 4. Very well seen.
B 5. Moderately well seen, though hazy.

D 1. Visible, though very hazy.
D 2. Just traceable; very faint and hazy.
D 3. Visible, but very woolly.
D 4. Visible, but hazy.
D 5. Its lower part is just traceable.

J 1. A nebulous ray, representing the upper parts of ν and o merged together, can be distinguished.
J 2. Traceable, though the extension is not so great as in J 1.

H ξ.—A delicate and nearly straight ray, which reaches to a height of quite 13′. It appears to be nearly radial, or but slightly inclined towards the east. It springs from the same part of the limb as ν. Its northern edge is pretty distinctly defined, owing to a very delicate rift, which can be traced down to within a few minutes of the limb.

B 1. Well seen.
B 2. Its lower part is visible.
B 3. Just traceable, though interfered with by a photographic flaw.
B 4. Well seen.
B 5. Well seen.
D 1. Visible, though rather woolly.
D 2. Visible, but woolly.
D 3. Only just traceable.
D 4. Just traceable, though very faint.
D 5. Lost.

H o.—A nebulous haze, which envelopes the whole of the H group. In several places there are traces of faint structures, which, however, cannot be made out with sufficient certainty to catalogue. It slowly fades off towards its outer edge, and can be traced to a height of 22′ over the centre of the group.

B 1. Well seen.
B 2. Lost.
B 3. Moderately well seen, though its outer edge cannot be traced, by reason of the fogging of the plate.
B 4. Well seen.
B 5. Moderately well seen; it has considerable extension.

D 1. Moderately well seen, except that it is cut off abruptly above.
D 2. The extension is very small.
D 3. Well seen.
D 4. Moderately well seen.
D 5. The extension is not great.

J 1. It can be traced to a height of 16′ or 17′.
J 2. The extension is not so great as in J 1.

Plate XIV.

I a.—A slightly curved and rather broad ray, extending to a height of about 12′. Its general axis is apparently radial, but it is slightly concave towards the H group.

B 1. Well seen.
B 2. Its lower part is visible.
B 3. Scarcely recognizable; much interfered with by a photographic flaw.
B 4. Well seen.
B 5. Quite visible, though hazy.
D 1. Traceable, though very hazy.
D 2. Lost as a separate ray.
D 3. Just traceable.
D 4. Lost as a separate ray.
D 5. Lost.

I β.—A nearly straight ray, broad and rather nebulous, about 11′ high; very similar to a, except that its upper part is fainter. It is separated from γ by a very distinct lighter space.

B 1. Well seen.	D 1. Moderately well seen.
B 2. Its lower part is well seen.	D 2. Just recognizable.
B 3. Scarcely recognizable as a separate ray.	D 3. Just recognizable.
B 4. Very well seen.	D 4. Lost as a separate ray.
B 5. Moderately well seen, though hazy.	D 5. Lost.

I γ.—An apparently straight ray, or spicule, reaching to a height of quite 15′. Its axis is but slightly inclined from the radial towards the west. Up to a height of 7′ it is comparatively slender, though not so delicate as E δ (the marked spicule of the southern rift). Towards its summit it becomes broader and more nebulous.

B 1. Very well seen.	D 1. Moderately well seen, though faint.
B 2. Only its lower part is very faintly seen.	D 2. Just traceable.
B 3. Moderately well seen, though hazy.	D 3. Moderately well seen.
B 4. Well seen.	D 4. Only just traceable.
B 5. Moderately well seen.	D 5. Lost.

I δ.—A branching structure, reaching to a height of about 22′. Its main stem is very decidedly inclined from the radial towards the east. Its two branches appear pretty symmetrical, and about on the same level.

B 1. Well seen.	D 1. Quite visible, though its summit is much interfered with by two minute transparent streaks.
B 2. Well seen, especially its slanting stem.	D 2. Traceable, though very woolly.
B 3. Moderately well seen, though hazy.	D 3. Visible, but very woolly.
B 4. Well seen.	D 4. Lost, or only just traceable.
B 5. Well seen.	D 5. Lost.

I ϵ.—A nebulous and apparently structureless haze, which appears to fill up the rift to a height of about 12′. It is so opaque that, seen by reflected light, only the summit of γ is visible.

B 1. Well seen.	D 2. Much interfered with by streaks.
B 2. Lost.	D 3. Well seen.
B 3. Visible, though, owing to the fogging of the plate, its outline is lost.	D 4. Moderately well seen.
B 4. Well seen.	D 5. Almost all lost.
B 5. Moderately well seen.	J 1. Visible, though it has not much extension.
D 1. Well seen.	J 2. Less extension than in J 1.

Mr. J. Norman Lockyer.

"Nature," Vol. v., p. 218.

12° 25′ N. } BAIKUL,
75° 0′ 6″ E. } 12th Dec., 1871.

[Looked at with the naked eye.] I did not want to see the prominences then, and I did not see them. I saw nothing but the star-like

decoration, with its rays arranged almost symmetrically, three above and three below; two dark spaces or rifts at the extremities of the horizontal diameter. The rays were built up of innumerable bright lines of different lengths, with more or less dark spaces between. Near the sun this structure was lost in the brightness of the central ring. . . . .

[Observed with a six-inch refractor.] The structure of the corona was simply exquisite, and strongly developed. I at once exclaimed—"Like Orion!" Thousands of interlacing filaments varying in intensity were visible; in fact, I saw an extension of the prominence-structure in cooler material. This died out somewhat suddenly, some 5′ or 6′ from the sun—I could not determine the height precisely—and then there was nothing; the rays so definite to the eye had, I supposed, been drawn into nothingness by the power of the telescope; but the great fact was this,—that close to the sun, and even for 5′ or 6′ away from the sun, there was nothing like a ray, or any trace of any radial structure whatever, to be seen.

Commander Maclear. 12° 25′ N., 75° 0′ 6″ E. — BAIKUL, 12th Dec., 1871.

MS. Reports of the 1871 Expedition.

I looked direct at the corona with the naked eye, and saw round the moon a bright glory like a six-pointed star. . . . . .

On turning to the 2½-inch finder of the refractor, the same radial structure was visible, but the extent was reduced, and it was not nearly so bright.

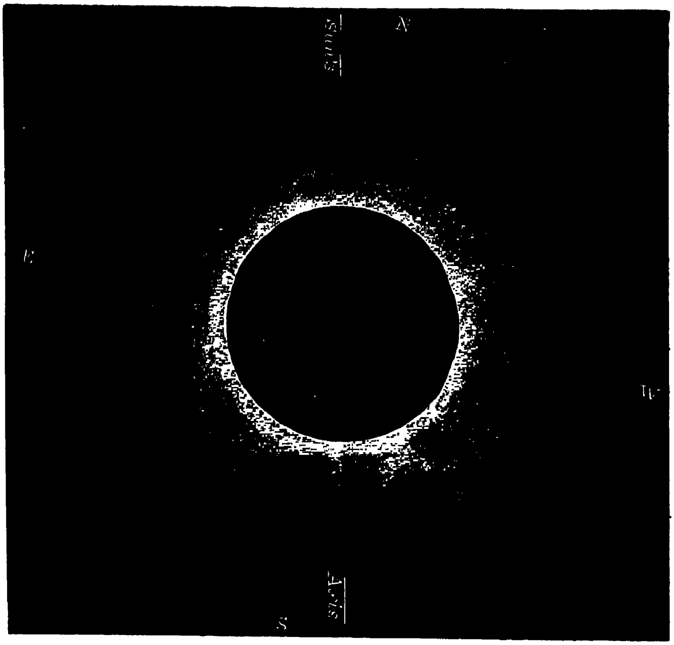
M. J. Janssen. 11° 27′ 8″ N., 76° 42′ 45″ E. — SHOOLOR, INDIA, 12th Dec., 1871.

Rapport à l'Académie relatif à l'observation de l'éclipse du 12 Dec., 1871. (Extrait des "*Annales de Chimie et de Physique*," 1873.)

(p. 19.) Autour de la Lune brillent plusieurs protubérances d'un rose corail qui se détachent sur le fond d'une auréole doucement lumineuse de couleur blanche, mate et comme veloutée. Les contours de cette couronne sont irréguliers, mais assez nettement terminés. La forme générale est celle d'un carré curviligne centré sur le soleil, et débordant celui-ci d'un demi-rayon dans les parties les plus basses, et de près du double vers les

General form of the corona quadrilateral, with curved sides. Within it many streaks were distinguishable which, starting from the moon's limb, curved together in the upper regions, forming groups which reminded M. Janssen of the petals of a dahlia. No change was observed as the moon passed over the corona.

angles. Aucune diagonale n'a la direction de l'équateur solaire. Cette couronne présente une structure très-curieuse dont on peut se servir pour résoudre plusieurs points de théorie. On y distingue plusieurs straînées lumineuses qui, partant du limbe lunaire, vont se rejoindre dans les hautes parties de la couronne. L'apparence est celle d'une ogive ou d'une pétale de fleur de dahlia. Cette structure se répète tout autour de la lune, et, dans son ensemble, la couronne figure comme une fleur lumineuse gigantesque dont le disque noir de la lune occuperait le centre. Je m'arrache à l'extase dans laquelle cet incomparable phénomène m'avait jeté un instant pour exécuter mon programme. J'examine si la couronne présente des différences essentielles au point de contact et au point opposé. Je ne trouve point de différence. Je suis alors quelques instants le phénomène, afin de voir si le mouvement de la Lune va apporter quelques changements importants dans la structure initiale de la couronne; or rien de semblable ne se produit. Ces épreuves me donnent la conviction complète que j'ai devant les yeux l'image d'un objet réel situé au delà de notre satellite, et dont celui-ci découvre les diverses parties par le progrès de son mouvement.



Janssen's drawing of the corona of 1871, December 12th.*

* The above woodcut has been made from a woodcut given in M. Janssen's report. It has been oriented from the north point as marked by M. Janssen, with the north pole of the sun's axis 11° 56′ to the east of the north point.

Col. Tennant.

11° 24′ N. } DODABETTA, near OOTACAMUND,
76° 43′ E. } 12th December, 1871.

Report by Col. Tennant on Observations made by order of the Government of India, p. 4. *See also* " Memoirs of the R. A. S.," Vol. xlii., pp. 1—32.

(p. 6.) In pointing for the spectroscope, I had an opportunity of seeing the corona well. The eyepiece employed was one with a magnifying power of about 35, and the aperture was reduced to $2\frac{1}{2}$ inches (65 mm.) by a very loose pasteboard cap, which I had intended to knock off just before totality. I, however, was so employed in following the cusp that I forgot this, and I doubt if I should have gained much: the image was very brilliant, and I find that on a dull, foggy morning the pupil of my eye has only $\frac{1}{10}$th of an inch (2·5 mm.) of diameter, so that with so low a power the greater part of the aperture of the telescope would have been wasted. I was obliged to use a low power, that I might be able to select points for spectroscopic examination in as large a field as possible. . . . .

(p. 6.) The corona was colourless; its brilliancy was greatest near the moon, and it faded off gradually at some distance; it was of variable width, but I saw no marked line of demarcation between an inner and an outer part. The general appearance I thought very much like No. 1 photograph, save that the glare near the moon was different, and the light extended farther, and shaded off more gradually.

There were numerous wedge-shaped portions of a grey tint, with their axes nearly radial, and darker in tint than their margins. These formed the rifts and the separations of the rays. They did not seem to me to extend down to the moon; but it must, I think, be evident that the extent of these rifts would vary greatly with the brilliancy of the image. I had occasion to examine the corona at 15′ or 16′ from the moon's limb; and with this part of it in the centre of the field, my impression was that though the brilliancy was markedly decreased, I was not near the limit of coronal light, and I could see the edge of the rift under examination stretching some distance farther. I saw no changes in the corona: the rifts I was examining seemed perfectly steady. One of the parts to which my attention was especially directed

was the nearly vertical edge of the rift to the right of No. 1 photograph; the other was a narrow rift very near the apparent lowest point of the moon, which was examined in two places.

Capt. J. Herschel.

11° 24′ N. } DODABETTA, near OOTACAMUND,
76° 43′ E. } 12th December, 1871.

Report by Col. Tennant on Observations made by order of the Government of India. *See also* "Memoirs of the R. A. S.," Vol. xlii., pp. 18, 19.

During the interval between records No. 6 and No. 7 . . . . I had time to look up at the sun. . . . . The corona was evidently, to my eyes, an assemblage of distinct and well-defined groups of rays, of which the strongest ones seemed to start directly from the central disc, so that the so-called rifts were only the interstices between the bundles of rays. The longest of the latter seemed to extend about one and a half diameters from the dark disc. I should add that the photographs which I have seen do not recall in any satisfactory way the impression which I received during those three or four seconds, the individual separate character of the ray groups being almost entirely lost.

Captain Waterhouse.

11° 24′ N. } DODABETTA, near OOTACAMUND,
76° 43′ E. } 12th Dec., 1871.

Report by Col. Tennant on Observations made by order of the Government of India. *See also* "Memoirs of the R. A. S.," Vol. xlii., p. 19.

The sum of my observations is that the first four photographs very fairly represent the eclipse as it appeared to me, both in size and general appearance. I saw no great changes in the form of the corona till perhaps towards the end, but of this I am not certain. I recollect carefully observing the general appearance of the phenomenon for some time, so that I might, if possible, make a sketch of it afterwards. I noticed particularly the triple-crown-like appearance of the vertex, and the two large rifts at the sides almost exactly as represented in the photographs; and had I tried to make a drawing I should have drawn much the same.

Mr. Hennessy. 11° 24′ N. 76° 43′ E. DODABETTA, near OOTACAMUND, 12th Dec., 1871.

Report by Colonel Tennant on Observations made by order of the Government of India of the Total Eclipse of Dec. 11—12, 1871. *See also* "Memoirs of the R. A. S.," Vol. xlii., p. 18.

Though I was debarred from looking steadfastly at the appearance of the eclipsed sun, I yet took every opportunity of glancing at it, and did so perhaps for two or three seconds at a time.

Thus viewed, the general outline of the corona looked like a sand-glass, or the figure 8, in which comparison the two re-entering angles must be understood as much exaggerated beyond the reality. There were no conspicuous prominences, but of those visible the ones about the vertex were the strongest. I saw no rays (or streamers) stretching greatly beyond the moon; and so far as I could estimate, the entire phenomenon was included in an annulus of half the moon's diameter around her edge. In brief, what I remember to have seen during totality is exhibited in the negatives 1 to 4: they contain details of which I was unconscious in making my hurried glances at the light, but I am not aware that the negatives are deficient in any respect.

Capt. Morant. 11° 24 N. 76° 43′ E. DODABETTA, near OOTACAMUND, 12th Dec., 1871.

Report by Colonel Tennant on Observations made by order of the Government of India. *See also* "Memoirs of the R. A. S.," Vol. xlii., p. 13.

Captain Morant was supplied by me [Colonel TENNANT] with a small reconnoitring telescope by Dallmeyer, of 1¾ inch (45 mm.) aperture and 14 inches (35·5 cm.) focus, giving with a power of 15 a singularly beautiful image.

It was mounted on a stand. His instructions were to endeavour to make two sketches, and generally to attend to the directions to direct-vision observers in the instructions of the British Association Committee. Captain Morant has furnished me with two sketches of the total phase, and notes answering the questions to be found in the instructions.

Captain Morant's sketches show very marked changes in the corona, but this hardly coincides with the account he gives. He says: "There

seemed a considerable general change over the whole corona, which made it difficult to draw its shape, but I observed no marked change of any kind. The rays in some places disappeared, and in others fresh ones came into view.

"Of the two dark rays or rifts (these are clearly rifts), the one to the right (S.) looking at the drawing, seemed to slide lower down towards the bottom of the moon as the eclipse advanced. The other, or left hand rift, did not change."

Mr. J. Boesinger.	10° 24′ N. 76° 47′ E.	OOTACAMUND, 12th December, 1871.

"Nature," Vol. v., p. 301.

I observed that the shape or form of the corona or glory which surrounded the eclipsed sun underwent changes in form even during the short space of two minutes; but you will easily see that an observer with no other means than an ordinary good telescope, his naked eye, and a photographic camera, was quite incompetent to draw any conclusion; suffice it, therefore, to say that the changes in the shape of the corona during totality can but be compared to the slow transformations of forms in a dissolving view apparatus, or perhaps more correctly to the changes of form and shape we observe in isolated thin clouds.

Mr. T. Gopalkristnah Pillay. **Mr. O. Annappa.**	12° 52′ N. 74° 54′ E.	MANDALORE, 12th December, 1871.

MS. Reports of the 1871 Expedition.

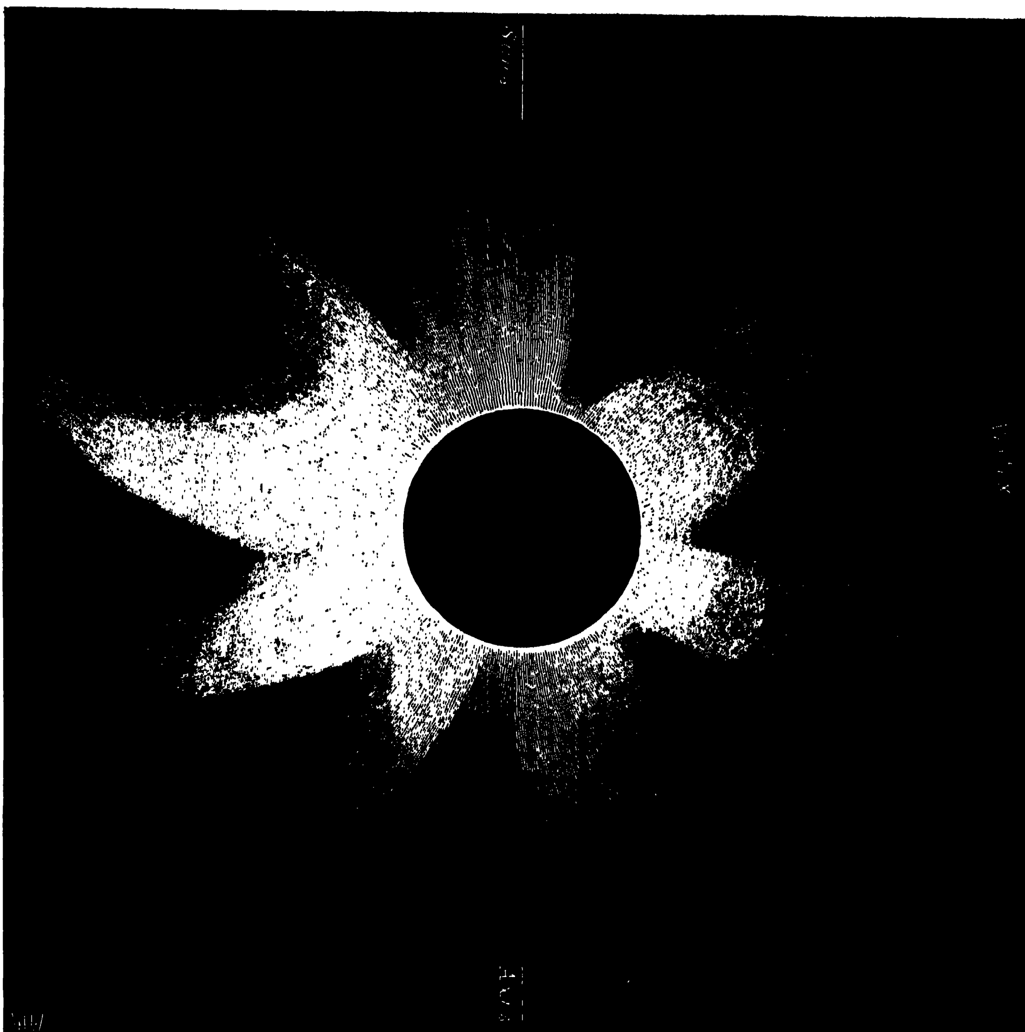
The following information was given in answer to printed questions which were issued by Mr. LOCKYER:—

QUESTIONS.	ANSWERS.
Has there been any change in the appearance of the corona during the eclipse? If so, specify what change.	The corona was not visible when the moon passed over the sun until totality.
Have especially the *dark rays* or *rifts* changed during the eclipse?	The dark rays or rifts changed size or widened themselves gradually as the moon eclipsed the sun.
Describe what has been unchanged throughout, and define its structure.	Nothing appeared to have remained unchanged during the eclipse.

Were the colours arranged *in layers* round the sun?	The colours were arranged in thick layers all round the visible portion of the sun.
Were the rays brightest near or far away from the moon?	The rays were brightest far away from the moon, and not near her.

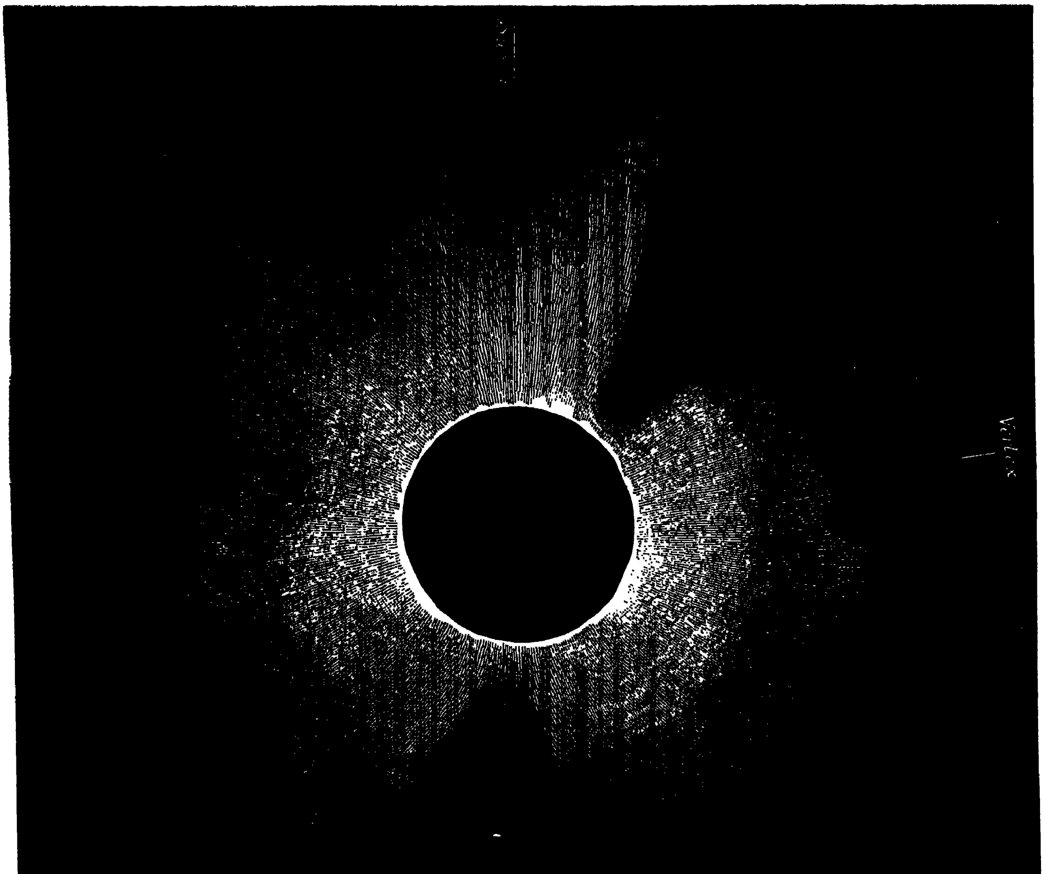
Mr. H. Holiday. 10° 25′ N. 79° 15′ E. RESIDENCY BUNGALOW, POODOOCOTTA, 12th December, 1871.

MS. Reports of the 1871 Eclipse Expedition.



Holiday's drawing of the corona of 1871, December 12th, as it appeared at the commencement of totality.

When Baily's beads appeared I removed the dark glass, but replaced



Holiday's drawing of the corona of 1871, December 12th, as it appeared to him at the middle of totality.*

it instantly, the light being still so brilliant that I feared to spoil my eye for after observations if I looked then. . . . . .

* The above woodcuts have been made from two highly finished water-colour drawings accompanying Mr. Holiday's MS. report. They have been oriented from the vertex. Assumed time of mid-totality $19^h\ 52^m\ 36^s$ local true time. North pole of sun's axis 79° 48′ to the left of the vertex.

A few seconds more, and I dropped the glass, and was rejoiced by the sight of a grand corona. Here is a sketch of its appearance. It resembled the most fantastic drawing in that page of the "Heavens" with six eclipses. The conical groups of rays were not so distinct as they appear there, but I saw at once what they were meant for. The most distinct ray, though not the longest, was that at A.* There was no protuberance visible on that side, but before centrality a group appeared precisely corresponding with it in position and breadth—though by the time I saw this group the ray had diffused itself and blended with its neighbours. In the same way the ray B coincides in position with the protuberance B, which only appeared when the ray was pretty diffused. The important rays at C also correspond with what appeared to be considerable protuberances, so far as I could judge with my little glass. Holiday's report.

After the centrality the corona, which had become much more diffuse than at its first appearance, maintained nearly the same form until on the reappearance of the edge of the sun. . . . .

As soon as the eclipse was over I came down from the roof and plunged my head into cold water, for I was violently excited, and before breakfast I had made three drawings† from my memoranda. I found that I could sketch with my right eye while my left eye was at the eyepiece with the greatest ease. I had not therefore to take my eye from the glass for a moment; and I think I may with confidence offer the drawings as correctly representing what I saw.

Mr. Francis Foenander.

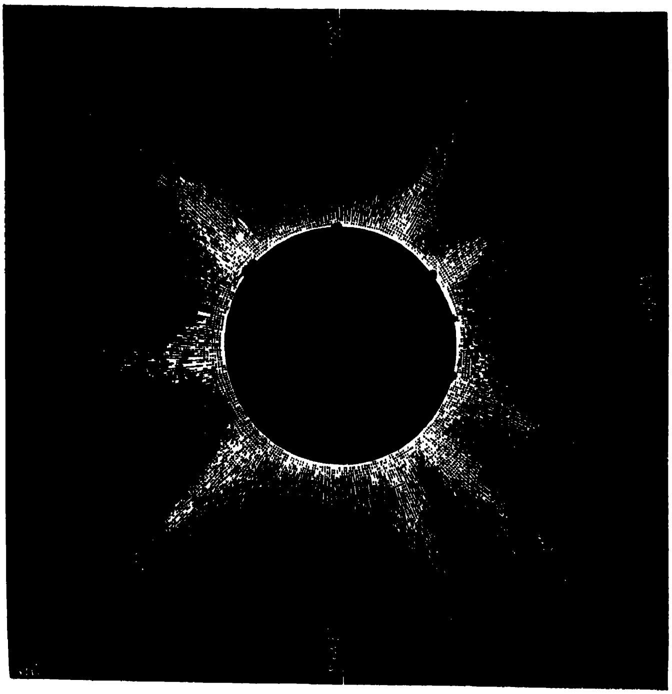
9° 40′ N. } JAFFNA,
79° 59′ E. } 12th Dec., 1871.

MS. Reports of the 1871 Eclipse Expedition.

[Four carefully finished drawings (signed "Francis Foenander" and

* The rays in the small diagrams on which the letters are marked do not correspond with Mr. Holiday's larger drawings. A is a little to the left of the lowest part of the unoriented image, B is a little below the western extremity of the horizontal diameter, and C refers to the rays near to the vertex.

† Only two drawings of the corona—viz., those from which woodcuts have been made—accompany Mr. Holiday's MS. report.



Drawing by Foenander of the corona of 1871, December 12th, made at the beginning of totality.*

evidently made at leisure after totality) were brought home with the MS. Observations of the 1871 Eclipse Expedition. They differ considerably from one another both as to the length and position of the pointed rays. The woodcut represents the first of these drawings. It has not been thought necessary to have woodcuts made from the others.]

Capt. G. L. Tupman.

9° 40′ N. } JAFFNA,
79° 59′ E. } 12th Dec., 1871.

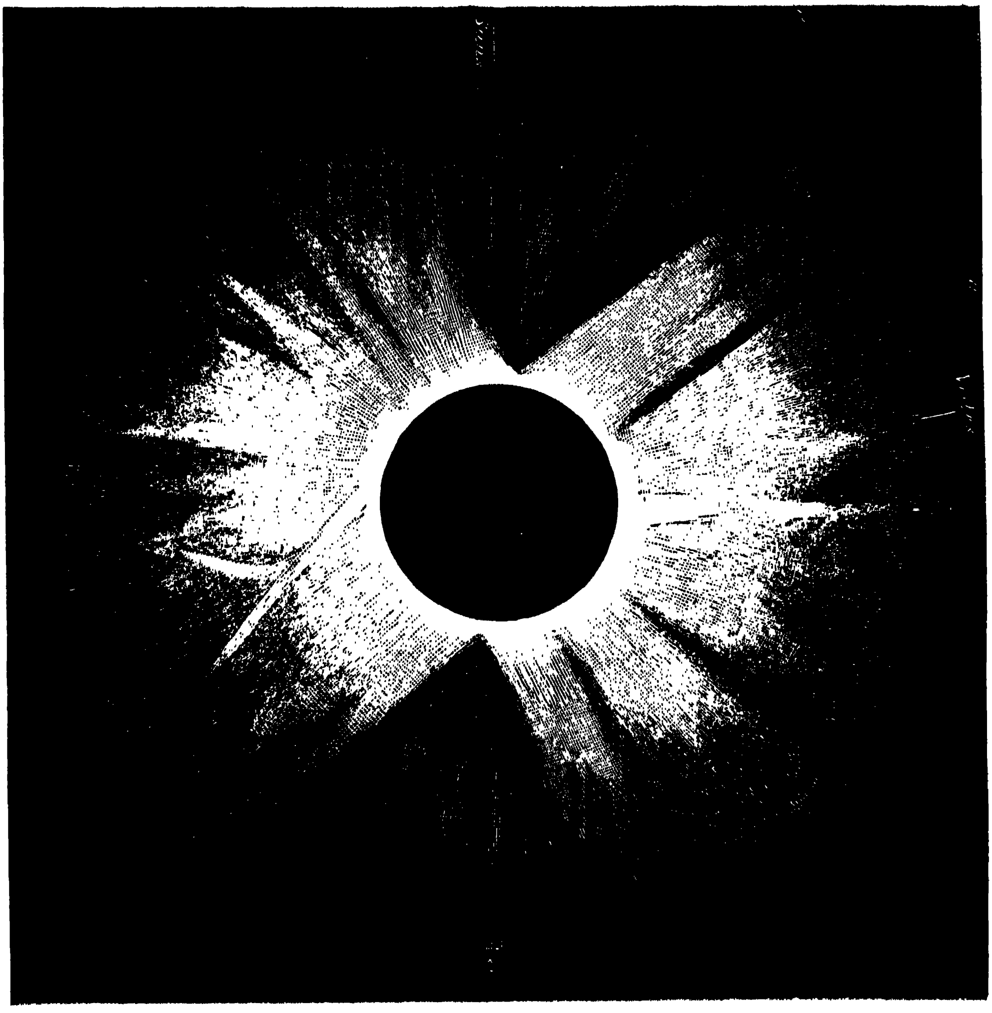
MS. Reports of the 1871 Eclipse Expedition.

Instrument.—A small telescope, the finder of a larger instrument, of 1⅜ inch aperture and 9½ inches focal length. The eye-piece was a single plano-convex lens of 2 inches focal length, giving a power of 4·8 and field of almost exactly 6°, of which, however, the outer degree was distorted; the definition over the 3° in the centre was very good. In the common focus was placed a plate of glass on which was engraved a circle 33′ in diameter.

I watched for the instant of totality in the finder, making use of a neutral-tint dark glass. The chromosphere became visible about the

* Oriented from the vertex. Assumed time of mid-totality $19^h\ 56^m\ 2^s$ local true time. North pole of sun's axis 80° 3′ to the left of the vertex.

same time as "Baily's Beads." It was of a decided orange colour. I removed the dark glass about 3^s before totality, but was too much occupied with obtaining the exact instant to notice the first appearance of the corona.



Tupman's drawing of the corona of 1871, December 12th.*

After giving the time signal, I took a leisurely survey of the corona. My astonishment was very great at finding it so different from anything I had expected. It occupied fully ⅓rd of my field, which

* Made from a chalk drawing by Capt. Tupman. Oriented from the vertex. Assumed time of mid-totality $19^h\ 56^m\ 2^s$ local true time. North pole of sun's axis 80° 3′ to the left of the vertex.

Capt. Tupman's report.

was 6° in diameter, and presented an amount of detail which would have taken hours to sketch or describe, so I confine myself to the most interesting features.

From the point *a* (see the diagram), a little to the right of the vertex,* a bright beam of light, of uniform width and perfectly straight,

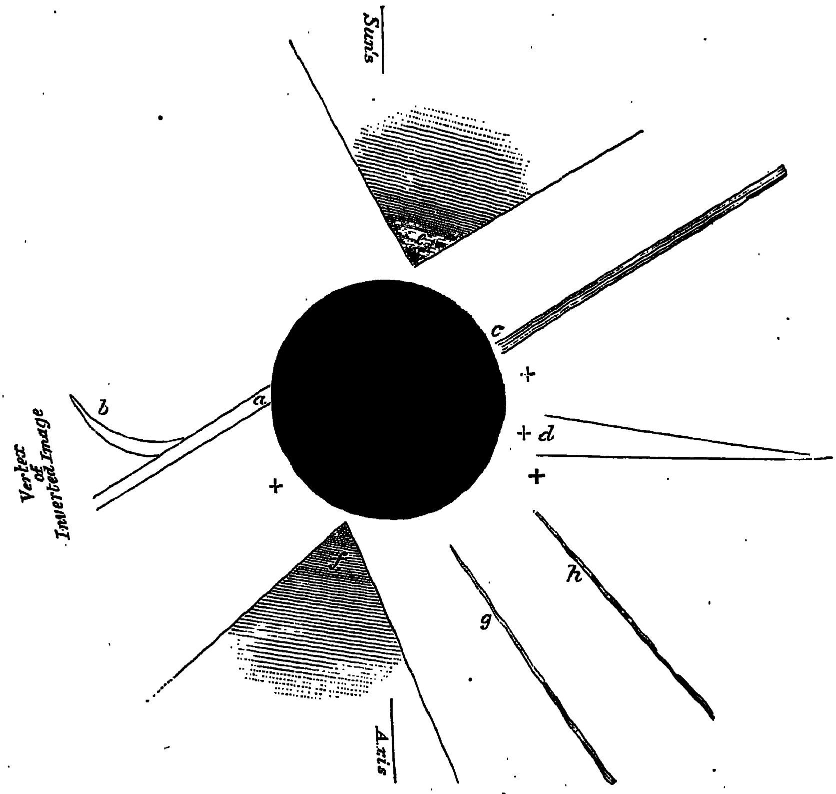


Diagram to illustrate Tupman's drawing of the corona of 1871, December 12th.

started from the very limb of the moon, where it was exceedingly bright, and terminated pretty suddenly at the distance of 28′ or 29′† from its base. It was inclined 30° or 35° to the normal at the point *a*. About $\frac{2}{3}$rds up—that is, at the height of about 20′—a curved ray (*b*)

* Capt. Tupman speaks always of the inverted image as seen in his finder.

† (*Note by Capt. Tupman.*) I was able to make pretty correct estimates of the height of rays by placing the small circle (engraved upon the piece of glass) in the common focus, a tangent exterially to the dark moon. The diameter of the circle subtended 33′.

seemed to spring from behind it, which faded away in a pointed manner about 12′ from its starting-point, the convexity being to the left. The edges of the straight ray were sharply defined, of the curved one less so.

At *e* and *f* were those peculiar appearances that had been called rifts. Never having read any description of them as seen in the telescope, I examined them as carefully as time allowed. The rift *e* was about a hundred degrees to the right of the vertex. Its apex approached within 4′ of the prominence stratum, possibly within 3′. It was bounded by sharply defined lines where the light of the adjacent corona was sharply cut off, rather than by distinct rays of brighter light. Whether the illumination within the rift was greater than that of the surrounding sky is a point that, to my great regret, I neglected to observe. But I noticed characteristic coronal rays on the rift. The rift *f* was similar in every respect, with the single exception that its sides were inclined at a somewhat less angle. In my sketch the sides of the rift *e* are inclined 85°, those of the rift *f* 75°.

At *c* was a very curious narrow rift, very dark, darker than the others, sensibly radial, and distinctly traceable to the distance of 45′ or 50′. It approached nearer to the prominence stratum than any of the others, and was about 1′ of uniform breadth.

At *d* was the largest of what may be called characteristic coronal rays. A pointed and sharply defined beam of uniform white light, 3′ or 4′ wider at the base (which was the chromosphere), and extending to the same distance as the rift *c*. . . . . . . The corona was made up of rays similar to these, some short, some faint, and of different degrees of intensity.

If the sphere were entirely covered with very pointed, self-luminous cones, with their axes radial, it would present the appearance of the corona.

There were fainter rays, or rather less luminous radial lines, at *g* and *h*, as well as numerous others not carefully observed.

I did not observe any change whatever during totality. My impression is there was none. . . . . . . The $2\frac{1}{4}^{m}$ passed very quickly. I was not in the least nervous or excited.

Mr. A. R. Dawson. $9^\circ\ 43'$ N. } $80^\circ\ 20'$ E. } KAITS, 12th Dec., 1871.

MS. Reports of the 1871 Eclipse Expedition.

I used an ordinary ship's telescope about two feet long, lashed by a pocket handkerchief to the back of a chair, and I removed none of its glasses . . . .

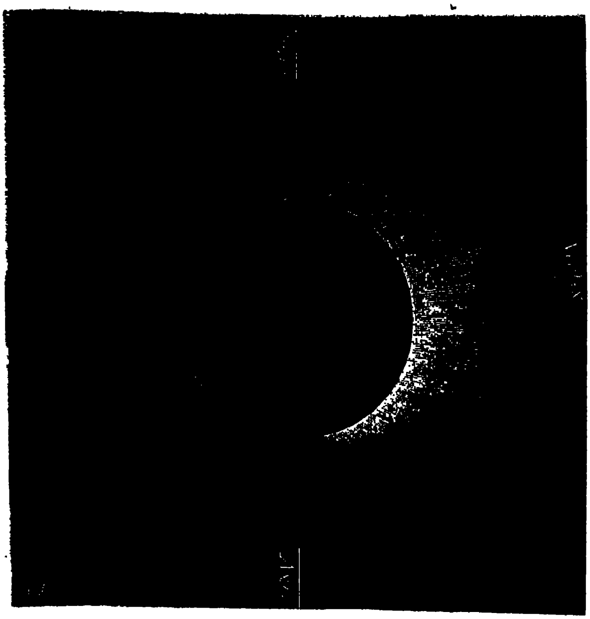


Fig. 1.*—Dawson's sketch of the corona seen just before totality.

At $7^h\ 46^m\ 30^s$ rays have suddenly sprung up from the northern arc of the black figure [the moon], they extend about half way down each of its sides. A small portion of the sun is still unobscured. A red protuberance appears first to the east of the unobscured part of the sun.

The rays are of a most delicate colour, in shape like the limb of a star-fish. The longer rays spring from the centre of the northern arc. They are shorter towards the east and west, and there are none towards the south. The longest seem to be about equal to one-half of the diameter of the black figure.

The colour of these rays as they appeared to me was that sometimes to be seen on a piece of common mother-of-pearl: a silvery pearl colour, with the least shade of mauve. What I saw at this moment I have depicted as well as I could in sketch No. 1.

The rays have burst out all round, and the sun is quite gone; there are two red protuberances to the south-south-east of the black disc. The rays are slightly brighter off the red protuberances. The length of the rays seems irregular: see sketch No. 2.

A red protuberance is apparent to the north-north-west, larger than those to the south-south-east. The rays are unchanged: see sketch No. 3.

The two red protuberances to the south-south-east have disappeared,

* These drawings have all been oriented from the vertex. Assumed time of mid-totality $19^h\ 57^m\ 39^s$ local true time. North pole of sun's axis $79^\circ\ 47'$ to the left of the vertical.

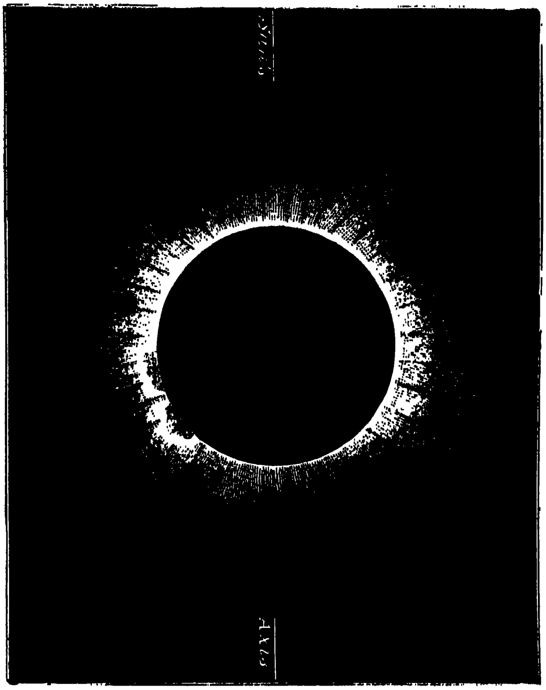


Fig. 2.—Dawson's second drawing of the corona of 1871.

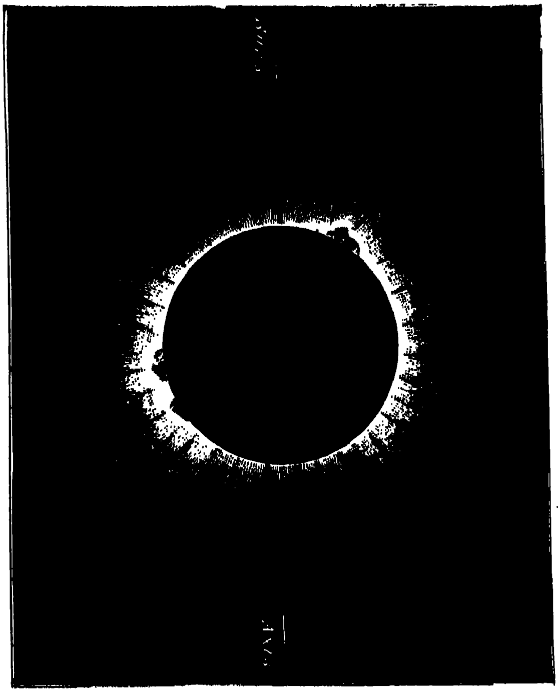


Fig. 3.—Dawson's third drawing of the corona of 1871.

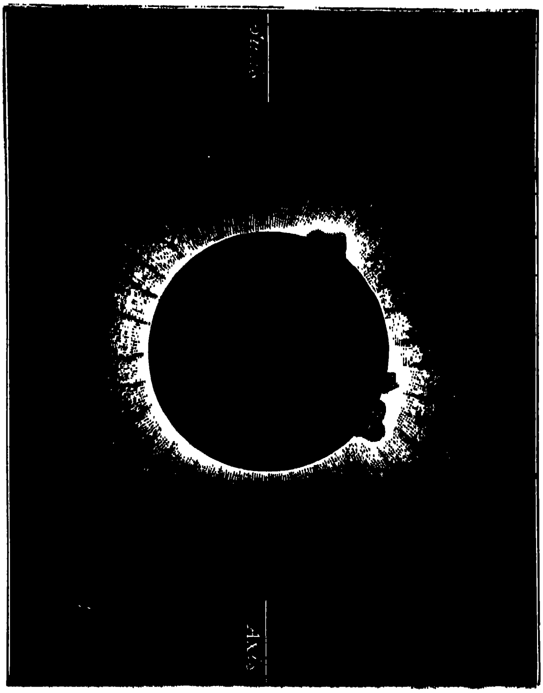


Fig. 4.—Dawson's fourth drawing of the corona of 1871.

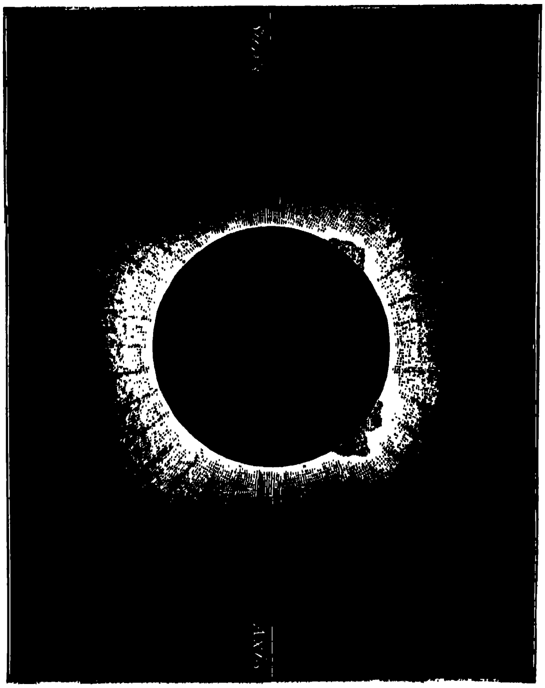
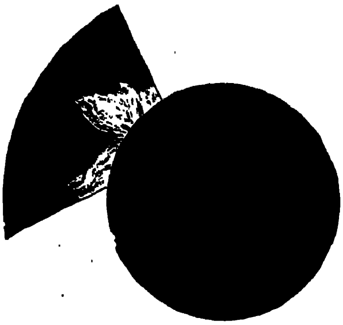


Fig. 5.—Dawson's fifth drawing of the corona of 1871.

and two others have burst out to the north-north-east. The rays are fainter: see sketch No. 4.

The two red protuberances to the north-north-east seem to have blended and increased in size: see sketch No. 5. When I looked again the sun had reappeared.



Pringle's drawing of a portion of the corona of 1871, Dec. 12th.

Mr. E. H. Pringle. [No place given.] 11th Dec., 1871.

MS. Reports of the 1871 Expedition.

Portion of corona seen through the finder of six-inch refractor. Apparent height 7′ or thereabouts; distinctly structural, and resembling a nebula. No change observed during the ten seconds of observation; colour purplish white.

Attempts to Photograph the Corona of 1871, *December* 12*th.*

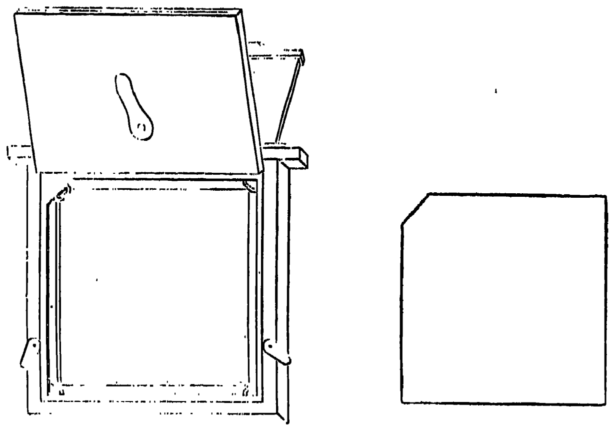
Mr. H. Davis. 12° 25′ N. 75° 0′ 6″ E. } BAIKUL, 12th Dec., 1871.

MS. Reports of the 1871 Expedition.

The photographic equipment was most complete, but as full details have appeared of similar outfits for previous eclipses, leaving little room for novelty in this respect, it will be necessary only to state the kind of instruments and process selected for use.

The objective, having a diameter of four inches and focus of thirty-three inches, was of the form called by the maker (Dallmeyer) the "rapid rectilinear." The camera was made to take photographs in the primary focus where the image of the sun had a diameter about three-tenths of an inch. It exactly resembles that used by Mr. BROTHERS—under unfavourable circumstances, but with such excellent effect—during the eclipse of 1870 at Syracuse. The camera was a long mahogany box, only just large enough to take the ordinary dark frames for plates five inches square. It was provided with a screw arrangement for focussing with great exactness. On the camera was fixed a finder of two inches aperture, and the whole was mounted on an iron pillar with an equatorial mounting and driving clock by Cooke,

Difficulties have more than once occurred when at, or after, former eclipses it has been found necessary to ascertain, as a first step towards correct orientation of the pictures, the position of each plate in its frame at the moment it was exposed. To prevent the recurrence of such difficulty, our dark frames had each a small fixed block in one corner, so that only glasses with a corresponding corner cut off could be used in them, and then only in one possible position.



Exposing frame and plate with corner cut off.

This plan was considered preferable to that of merely scratching a mark on the glass, as the mark might be accidentally overlooked and misplaced.

The negative collodion process was that chosen, and a large stock of tested chemicals was provided. I took with me also written instructions from Lord Lindsay as to the duration of time deemed necessary for the exposure of each plate in the totality series of photographs.

We arrived at Galle (Ceylon) on the 27th of November, and I borrowed a convenient portable dark-room on wheels of Capt. Bailey of that place; we deposited our first consignment of observers, steamed along the west coast of India (only stopping to plant astronomers), and arrived, diminished in number to four, at Baikul on the 4th of December. Here we were met by some gentlemen of the Indian Civil Service, who had made arrangements for assisting and entertaining us.

Mr. Lockyer chose for operating ground the summit of a tower within an old ruinous fortress; while I secured an excellent position on a high plateau adjoining the tower. The sky room was ample, with a nearly unbroken horizontal line from east to south, and shelter from the wind from other quarters in the fortress-walls and abundant foliage; and, after a day or two, further protection was given by a wattled awning of palm-boughs screening the dark-room and mounted camera.

In four days the equatorial had been placed and adjusted, the

apparatus all unpacked, chemicals re-tested, and all made ready for methodical practice.

The silver-bath (neutral, and of 30 grains strength) was found to work well with some specially prepared chromo-iodized collodion (Thomas's), giving great rapidity and soft graduation of tint, with perhaps an inseparable slight tendency to fog; but the trials were considered satisfactory, as hardness in the negatives was to be carefully avoided. The best developer tried was a simple iron solution:—

Protosulphate of iron	1 oz.
Glacial acetic acid	1 oz.
Alcohol	½ oz.
Water	33 oz.

In the daily drill assistance was kindly given by Mr. J. W. Cherry, who undertook to pass the dark-frames to and from the exposer, by Mr. Bradshaw as time-keeper, and by Major Standers to remove and replace the loose cap of the camera as required. We soon found that five plates could easily, and without dangerous hurry, be exposed during a totality of 123 seconds, giving each the time of exposure which Lord Lindsay had considered desirable, and leaving seven seconds for changing each dark frame.

On the morning of the 12th of December the sun, soon after rising, cleared the distant hills with their light low-lying eastern mist, and shone upon us at our posts with scorching brilliancy:* thenceforward the weather was everything that could be desired—clear, calm, and cloudless. Mr. Cherry had in charge an extra dark-frame containing a dry sensitive plate; and his instructions (which were well carried out) were to take on it, in a certain known position, an instantaneous photograph of the sun soon after first contact; then to stop the driving clock for six minutes, and take a second photograph on the same plate; then make another stoppage for six minutes, and so on until five photographs had been obtained on the same plate. We had intended to take a second set of partial-phase pictures in the same manner after totality on a second dry plate, but accidentally breaking this, both series were worked on the same plate. On developing the dry plate some hours after, the ten small representations of partial phases

* Assuming the time of mid-totality at Baikul to have been $19^h\ 32^m\ 19^s$ local true time, the sun's centre must have been $15^\circ\ 33'$ above the horizon.

Davis's report on photographic operations.

came out accurately disposed at equal distances apart, as expected; and although the photography was bad, through some fault of mine, the plate has since fully answered its main purpose in furnishing what Mr. RANYARD considers a very trustworthy guide to the orientation of the negatives of totality.

About twenty minutes before totality was due five plates were carefully prepared and each put into its frame with wet red blotting-paper at the back.

On returning to the camera, I saw that the clock was running smoothly, while a brilliant crescent image of the sun occupied most steadily the centre of the focussing-screen.

We then took our places with two or three minutes to spare; during these I watched, through the finder, the sun rapidly thinning to a curved silver thread, which finally broke and vanished. At the instant I started the time-keeper with "One"; at "Three" Major Standen removed the camera-cap, and plate No. 1 was being exposed:—

No. 1	exposed	from	3rd	sec.	of totality	to 18th.	Duration	of	exposure	15	sec.
2	,,	,,	25th	,,	,,	,, 35th	,,	,,	,,	10	,,
3	,,	,,	42nd	,,	,,	,, 82nd	,,	,,	,,	40	,,
4	,,	,,	89th	,,	,,	,, 99th	,,	,,	,,	10	,,
5	,,	,,	106th	,,	,,	,, 123(?)	,,	,,	,,	17(?)	

All went well until, at the end of the fifth exposure, I closed the slide before the camera was capped, as the sun appeared to be bursting out. In consequence, the instrument was jerked, and has left the effect as a sort of "fault" or sun-slip in the fifth negative. The rash proceeding has also prevented the attainment of extreme accuracy as to the time of exposure of this fifth plate: it was not, however, more than 18 seconds, nor less than 16.

The five plates having been exposed, and totality ended, I took the frames into the dark-room and began developing. No. 1 (15 sec.) was quite satisfactory;—a very narrow ring at once appeared, and went on extending in broad rays; these stopped somewhat suddenly, and the development was just pushed far enough to warrant one in thinking that there was no more corona to come, and yet not far enough to clog up any detail existing in the denser parts of the picture. Neither

Davis's report on photographic operations.

this nor any other negative of the series required intensifying. It was washed and dropped into its bath of weak hyposulphite of soda for slow fixing.

No. 2 (10 sec.) developed badly, with a fog all over the plate and with the corona weak and of little extent. Experience having taught me that prolonged development in such a case only makes bad much worse, this negative was very lightly developed, and a picture of some value secured.

No. 3 (40 sec.) burst out at once, with what I conside red its fullest extent of corona, and a general fogging like that of No. 2; it was also treated to a light repressed development in a similar manner, much to my regret since. Sustained development might, and most probably would, have spoiled the photograph by forming a dense, uniform deposit all over the plate: still, at all hazards, the development should have been forced with the hope of showing, however dimly, those coronal limits which it was so important to depict. That such limits are not reached in No. 3 is proved by Nos. 1 and 5 showing a slightly greater extension of corona than this long exposed negative.

No. 4 (10 sec.) was fully developed: a clear, good photograph, greatly resembling No. 1, with the corona extending very nearly as far as that of the first negative, although the exposure was so much less. Considering that the collodion, the silver-bath, and the mode of development were precisely the same with the two plates, there seems but one way to account for the nearly similar results of the two very dissimilar exposures,—the power of the light (visual probably, actinic more certainly) fell off rapidly towards the outer extremities of the corona, say at 25′ from the moon's limb, and consequently increased exposure failed to give proportionately increased corona beyond that distance. This agreed very well with what I observed in the finder, and still better with the naked-eye observation.

No. 5 (17 sec.) came out rather quickly and well. The effect of the movement of the camera appeared most injuriously in a curved streak on the outer part of the corona, on that side at which the sun was about to appear; and the "fault" tends to confuse appreciation of the height of the corona at this part. I am inclined to consider the height is greater here than in any of the other negatives.

After fixing, washing and drying the negatives, there remained but

one task to perform before packing-up for the return to England: it was necessary to discover, if possible, the reason why plates 2 and 3 should be comparatively bad, in company with others so much better which had been prepared and used under similar conditions. Itwas found that although baths 2 and 3 had been filled up from the same stock-bottle of silver solution as the others, these two only had been used pretty freely for trial plates before the eclipse, and this appears to have been sufficient to throw them out of order. These two baths had become slightly alkaline, while the others remained neutral.

Col. Tennant. **Mr. J. B. N. Hennessey.** **Captain Waterhouse.**	11° 24′ N. 76° 43′ E.	DODABETTA, near OOTACAMUND, 12th Dec., 1871.

Report of Col. Tennant on Observations made by order of the Indian Government, p. 8. *See also* "Memoirs of the R. A. S.," Vol. xlii., pp. 11—14.

(p. 11.) The photographic operations were under the general charge of Mr. J. B. N. Hennessey, of the Great Trigonometrical Survey, with whom was associated Captain Waterhouse, for the special purpose of attending to the technical manipulations.

The apparatus was originally intended to have been made in India, and I had intended to borrow a lens from the Surveyor-General's Office; but it was very fortunate that Dr. Huggins undertook to provide all that was needed, for unforeseen difficulties arose, and I was unable to give such constant attention as was necessary to the details. Dr. Huggins was assisted by Mr. Brothers, of Manchester, whose experience of the eclipse of 1870 was valuable, and who kindly fitted up a box of chemicals and apparatus for us.

The lens employed was one of Dallmeyer's largest "rapid rectilinears," of 4 inches (10 cm.) aperture, and about 33 inches (83·7 cm.) equivalent focus. This was attached to a cylindrical metal camera, which was mounted on an equatorial stand, and a clock was provided to keep the camera automatically up to the object to be photographed. The cradle carrying the polar axis, and clock, had a slight rocking motion on the pillar, which gave sufficient adjustment for latitude, while for azimuth the whole apparatus, pillar and all, had to be moved.

Tennant's report on photographic operations.

By fixing approximately the meridian with a compass, it was found that the bringing of the polar axis into position with sufficient accuracy was not very difficult.

The clock was that belonging to Mr. Airy's instrument, which, not being wanted there, was made available for the photographic apparatus. When it was unpacked it was found that the steel axes were a good deal rusted, but fortunately none of the working portions were damaged, and when cleaned and put together the clock seemed to go well and pretty regularly; but it stopped occasionally without apparent cause, and on one occasion it was found that a clamp, binding together two parts of a connecting rod, slipped, and allowed the clock to go without acting on the camera. It was hoped that sufficient precautions had been taken to prevent the recurrence of any accident of this sort during the eclipse. One has, however, only to look carefully at photograph No. 6 to see that during the twenty seconds of exposure that were given to it, the clock was not doing its work, and a comparison of the trace of the northern prominence with the moon's diameter shows that, in fact, the impression is the whole effect of diurnal motion.

The camera was furnished with six dark slides, each to hold a plate five inches square, and the whole had been well considered with the advantage of Mr. Brothers' advice, so that the changes could be rapidly made. The stand stood on a bare-surfaced rock, and the whole instrument was covered by an observatory tent.

We had intended to use Thomas' photographic tents for the operations of preparing the plates and developing the pictures; but finding that there would be facilities for building a hut for the purpose, and considering the exposed summit of the hill, the entire want of shelter for the tents, and the great difficulty of illuminating them artificially, it was determined to make a hut of bamboos, wood, mats and turf, which should hold all the materials, and at the same time serve as a dark-room. This was done by Mr. Willis.

The floor was about 12 feet by 6 feet, and there was a good broad shelf at each end—one for sensitizing and one for developing the plates—while a narrower shelf ran along the north side of the room, and carried the fixing bath, washing troughs, etc. The inside was well lined with matting, to keep away the dust. A pane of yellow glass was placed in

the door, but it was thought necessary to provide candles as well for illumination.

Tennant's report of photographic operations.

I had originally intended that the photographs should be taken by Mr. De la Rue's procedure, with similar chemicals to those we had used in 1868.

I had abundant reason then to be satisfied with the delicacy of detail, and I felt that now, with so small an image, much might depend on magnifying. With this in view, I had some nitrate of silver fused; and a considerable quantity of water was distilled from a solution of potassic permanganate in a glass retort, into a glass receiver, whence it was transferred into clear glass bottles. Captain Waterhouse and I tried a number of experiments with the various chemicals, of which I may give the following general results.

It was very difficult to make a bath which should *certainly* work cleanly in Mr. De la Rue's process, and was extremely easy to make this preliminary when using a bromo-iodized collodion. The deposit from simply iodized collodion with a pyrogallic acid developer was unquestionably the finest: it gave the most delicate detail, and admitted best of being magnified, while the deposit got by a bromo-iodized collodion, and an ordinary protosulphate of iron (ferrous sulphate) developer was worst; but by using sugar freely in the iron developing solution (an expedient I have adopted for years), the deposit on bromo-iodized collodion became very nearly as fine as with pyrogallic acid, while the whole procedure became simple and certain. At the same time it was evident, as I had long known, that the use of sugar enabled objects having varying degrees of illumination to be depicted in some detail.

I was, however, most unwilling to give up Mr. De la Rue's process, which I had tried; and I believe that by timing the exposures suitably we should get all the grades of the corona, not indeed on one plate, but among the plates. When we reached Ootacamund, however, and began experiments, we were met by the bath difficulty at once, and this was only got over partially by re-distillation of the water. Captain Waterhouse, therefore, strongly urged that he should use the less difficult mode of proceeding, with which he was more familiar, and which, especially with the modification of adding sugar to the developer, brought out a greater range of intensities; and this was resolved on.

Tennant's report on photographic operations.

The following, then, was the working method :—

The *collodion* was partly Thomas', and partly a mixture of equal parts of Thomas' and Mawson's: in both cases bromo-iodized. The *bath* contained about 30 grains of nitrate of silver per ounce (6·9 per cent.), and was as nearly neutral as possible.

The developer had the following constitution :—

Ferrous sulphate	15 grs. per oz.	3·44 per cent.
Table sugar	15 ,, ,,	3·44 ,,
Glacial acetic acid*	10 ,, ,,	2·29 ,,
Spirit of wine	15 minims ,,	3·44 ,,

The negatives were not intensified, but each, as developed, was placed in a dish of water till its turn came to be fixed in a strong bath of sodic hyposulphate.

A good deal of time was spent on the two days before the eclipse, and, finally, on the morning itself, in rehearsal of their parts by those who were to share in the work. Mr. Hennessey undertook the making of the exposures and recording the times, etc., from Mr. Willis' counting off a chronometer; and Captain Waterhouse, who prepared and was to develop the plates, took the duty of changing them rapidly. The proceedings began, notwithstanding the bad promise of the weather, by commencing the preparation of the plates some twenty minutes before the calculated time of totality. While Captain Waterhouse was busy with this, Mr. Hennessey carefully focussed on the fine cusps, and all being ready, the party took their positions about five minutes before the commencement of the total phase. . . . A few seconds before totality, Mr. Willis began calling the seconds, keeping his attention fixed on the chronometer face; when the sun disappeared, he was warned, and began to count; and Mr. Hennessey recorded the moments at which he opened and closed the lens on a card fastened on the back of his hand, the seconds being counted from the commencement of totality.

I had arranged that the exposures should be in succession 5^s,

* (*Note by Col. Tennant.*) I am very averse to the use of acetic acid. It is quite possible to use 50 grains of ferrous sulphate per oz. with a suitable amount of sugar and without acid; and I believe the acid restrains the faint impressions more than those of a stronger light.

10^s, 15^s, 15^s, 10^s, 5^s, on the supposition, of course, of a clear sky.* The state of the weather, however, put out of the question the possibility of connecting the duration of the exposure with the amount of detail on the plate; while, on the other hand, the adherence to our programme would have risked some plates being entirely under-exposed. Mr. Hennessey, therefore, resolved to abandon all rule, and to judge of the amount of exposure by his estimate of intensity of the light. The exposures were then, counting from the beginning of totality:—

No.	1	exposed at	4^s,	shut off at	19^s.	Exposure	15^s.
"	2	"	34^s,	"	44^s	"	10^s.
"	3	"	55^s,	"	63^s	"	8^s.
"	4	"	74^s,	"	80^s	"	6^s.
"	5	"	88^s,	"	93^s	"	5^s.
"	6	"	103^s,	"	123^s	"	20^s.

The light was only just shut off from the last plate as the sun reappeared.

Capt. J. R. Hogg. 9° 43′ N. 80° 10′ E. JAFFNA, 12th Dec., 1871.

MS. Reports of the 1871 Eclipse Expedition.

[Photographs which are at present in the possession of the Royal Astronomical Society were taken by Capt. Hogg at Jaffna† with two cameras, one of 26 inches and the other of 16 inches focus. They are so fogged that only the details of the lower parts of the corona can be made out on them.]

Herr C. Dietrich. 7° 48′ S. 109° 5′ E. TJEBATJAP, JAVA, 12th Dec., 1871.

[From a letter of Dr. OUDEMANS, published in "Nature," Vol. ix., p. 61, it appears that Herr Dietrich's photographs were taken with "a photographic lens of short focus."

* Assuming the time of mid-totality at Dodabetta to have been $19^h\ 40^m\ 16^s$ local true time, the sun's altitude must have been 17° 45′.

† The sun's altitude at Jaffna was 21° 53′, assumed time of mid-totality $19^h\ 56^m\ 2^s$ local true time.

Enlarged positive copies upon glass of Herr Dietrich's photographs were sent by Dr. OUDEMANS to Lord LINDSAY in 1872; these copies are now in the possession of the Royal Astronomical Society. From an inscription on them it appears that the first was taken with an exposure of half a second at Tjebatjap,* Java, and that the other negative was taken with an exposure of one-third of a second.]

* Assuming the time of mid-totality at Tjebatjap to have been $22^h\ 51^m\ 58^s$ local true time, the sun's altitude must have been $67^\circ\ 39'$.

Eclipse of 1874, April 16th.

We do not possess any photographs of the corona visible during this eclipse; but the drawings given by Mr. STONE, in his report published in Vol. XLII., prove the corona to have been very extensive. In Mr. WRIGHT's drawing the rays extend to a distance of more than three solar diameters from the sun's limb; and Mr. STONE traced the 1474 line with a spectroscope to more than a degree from the sun's centre. Corona very extensive.

The corona seems to have been of the same type as that observed during the eclipse of 1868·6. The drawings made by Mr. WRIGHT and Miss ALICE HALL were very similar to Capt. BULLOCK's 1868 drawing: they represent the corona with four great groups of rays, the axes of which make angles considerably greater than 45° with the sun's axis.

Mr. HENRY HALL's drawing is of the quadrilateral type, somewhat similar to the quadrilateral drawings made by POGSON, WALKER, and WINTER in 1868; but in Mr. HALL's drawing the equatorial diameter of the quadrilateral outline is decidedly greater than the polar diameter, and the area within the quadrilateral outline is considerably less than in the 1868 quadrilateral drawings. Quadrilateral drawings.

Messrs. BRIGHT and DEGERMAN's drawings may also be described as of the quadrilateral type. The equatorial diameter of the quadrilateral figure is still greater in proportion to the polar diameter than in Mr. HALL's drawing, and the area within the quadrilateral outline is considerably greater. All the drawings appear to be contour drawings; and, as suggested by Mr. STONE, the great differences between them may no doubt be explained on the supposition that they correspond to areas of different degrees of brightness. None of the observers seem to have noticed any structures within the field of the corona. In the case of Miss ALICE HALL's drawing, it is especially stated (p. 49), that "the shading is intended simply to represent that the light of the corona faded away by insensible degrees as the distance from the sun's centre increased," and in the other shaded drawings there is nothing that appears to be intended to represent coronal structures. It would seem therefore probable that such coronal structures as may have existed were not as striking, compared with the background on which they were seen projected, as in the No drawings of coronal structures.

coronas of 1860 and 1871; and as far as such negative evidence goes, there would appear to be a similarity between the corona visible during this eclipse and that observed during the eclipse of 1870, though the general outline of the coronas visible on the two occasions differed greatly.

Sun spots. Dr. Wolf gives as the relative monthly number of sun spots for April 1874 (49·1) a number which about corresponds with that given for the period of the eclipse of 1868, and is only a little more than one-third as great as that given for the period of the eclipse of 1870.

Mr. E. J. Stone. 29° 14′ S. 17° 40′ E. Klipfontein, 16th April, 1874.

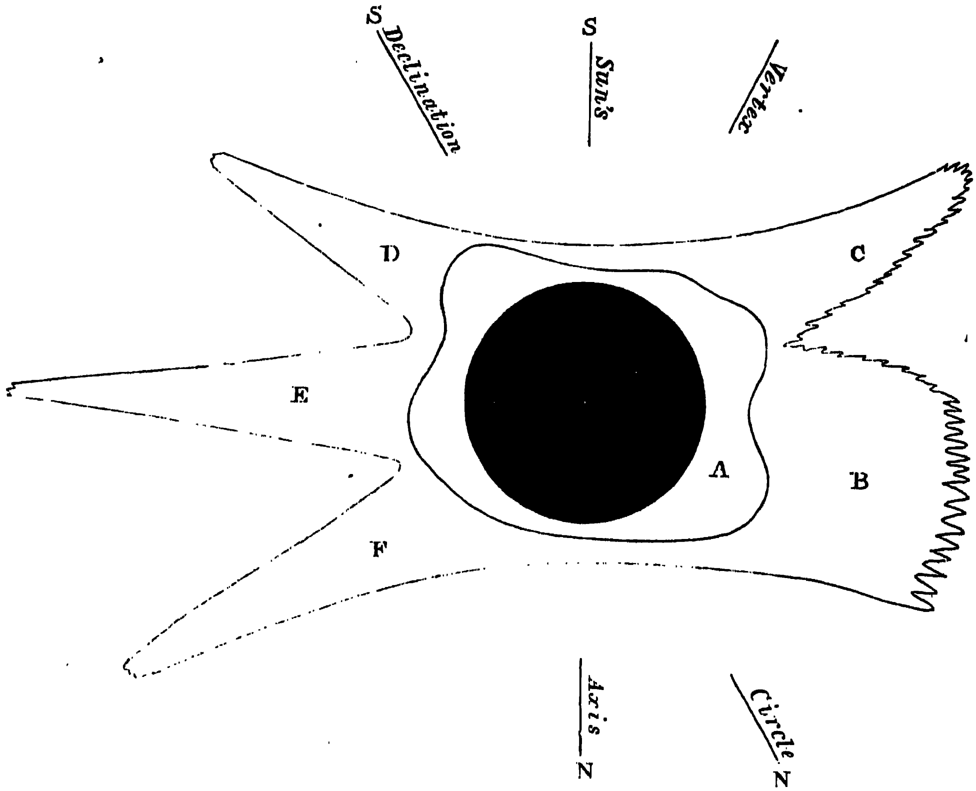
"Memoirs of the Royal Astronomical Society," Vol. xlii.

(p. 44.) My first impression was that the corona consisted entirely of a pink-coloured irregular ring. The rose-coloured prominences were seen clearly, and were to me of a much deeper red than the inner corona. When looking carefully for the parts beyond this inner corona, (or, as I at the time regarded it, the chromosphere,) I saw most distinctly, and without any difficulty when attention was fixed upon it, the branches of the outer corona marked C and B in the composite picture. I believe that the drawing of these portions of the corona by Miss Alice Hall is correct, except that in her drawing the edge of B is divided into something like four brushes. The outline appeared to me much more irregular than this; and Miss Hall, directly after the eclipse, expressed an opinion to much the same effect—viz., that there was too much detail in this part to be accurately drawn in the time ($3^m\ 20^s$) available. I feel certain that the visible extent of branch B has been under rather than over-extended in Miss Hall's drawing.

[In the composite drawing, the outer outline was taken from Miss Alice Hall's drawing, and the inner outline from Mr. Henry Hall's drawing. They were seated side by side at the same table.]

(p. 46.) The drawings were made on prepared paper divided into sectors of 30°, and, for estimations of distances, into circles with radii two and three times the radius of the inner circle. The direction of the vertical plane was carefully determined in accordance with the general instructions of my letter. But, notwithstanding the precautions taken,

I was astonished to find, when after the termination of the totality I looked at the drawings, that there was not a trace of any similarity between them. Mr. Henry Hall's outline did not extend to quite 11′ from the moon's limb. Miss Alice Hall's extended to 1° 40′ from the moon's limb in one direction, and to very large angular distances in other directions. I had myself examined, with the spectroscope, the corona to a distance from the moon's limb more than five times as great



Mr. Stone's composite drawing of the corona of 1874, April 16th.

as the corona represented in Mr. Henry Hall's drawing. I was able to speak of the general accuracy of Miss Alice Hall's drawing of the branches marked B and C in the composite drawing; and my wife, who had seen the eclipse well through the finder, expressed her agreement also with the general accuracy of Miss Hall's drawing. But Mr. Henry Hall's skill and practice as a mechanical draughtsman entitled his drawing to be received with every confidence, and he was perfectly satisfied with the drawing made.

Eclipse of 1875, April 6th.

The copies of the photographs given on plate 16 of the *Philosophical Transactions* for 1878, from which the outline woodcut given on the opposite page has been made, show four groups of synclinal structure situated nearly symmetrically with respect to the position of the sun's axis as determined by Messrs. LOCKYER and SCHUSTER. The axes of these synclinal groups, as shown in the photographs, make angles of more than 45° with the sun's axis. In the drawing by the Hon. H. N. SHORE, the north-western and south-western of these synclinal groups can easily be recognised, and possibly also the north-eastern and south-eastern groups.

Synclinal groups.

Coronas of April 1874 and April 1875.

The corona visible during this eclipse seems to have been similar in type to that observed during the eclipse of the previous year. But judging by the plates given in the *Phil. Trans.*, the details of coronal structure appear to have been more easily recognized during this eclipse than on the former occasion.

The fact that on both occasions the eastern side of the corona was somewhat smaller and less broken up than the western side, must probably only be regarded as accidental, as it can hardly be assumed that similar heliographic longitudes of the corona occupied similar places with respect to the moon's limb on the two occasions. From our knowledge with respect to the rotation of the photosphere, derived from observations of sun spots, it appears that different heliographic latitudes have different rotation periods,*—and it seems not improbable that a similar law would hold with regard to the corona.

Sun spots.

WOLF gives 20·5 as the relative monthly number of sun spots for April, 1875, showing that the solar activity, as indicated by sun spots, was not half as great as at the period of the eclipse of the previous year.

* See CARRINGTON'S "Observations of Sun Spots from 1853 to 1861," pp. 221-5. There appears to be a difference of more than two days in the rotation period of latitude 14° N. or S. of the photosphere and latitude 45° N. or S.

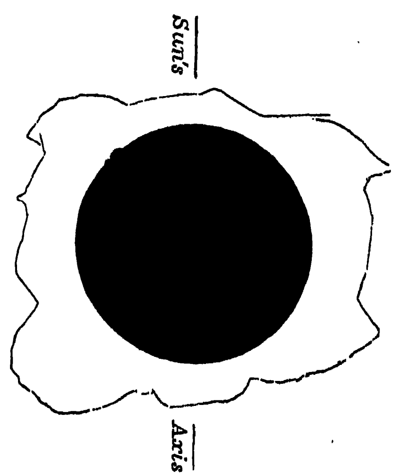
Mr. J. Norman Lockyer.
Dr. A. Schuster.

SIAM,
6th April, 1875.

Phil. Trans., Vol. clxix., Part I.

(p. 152.) Eight photographs were obtained by means of a small camera belonging to Mr. Beasley, the object-glass having a focal length of about 13 inches. The camera was not moved by clockwork, but during the short exposure the sun's movement, though visible, does not materially affect the results. The times of exposure were 2, 4, 8, and 16 seconds, and two photographs of each exposure were obtained. As these two sets show exactly the same phenomena, we need only consider one set—remembering, however, that the other set excludes the possibility of any of the results being affected by irregularities in the collodion-film. . . .

Looking over one set, we are first struck by the rapid increase in the extent of the corona through an increase in the time of exposure: the last of the photographs, having been exposed 16 seconds, shows an extent exceeding the diameter of the sun.



Outline drawing made from photographs of the corona of 1875, April 6th.*

The next point of interest is the symmetry of the outer corona round the sun's axis. This symmetry was dwelt on by Mr. E. J. STONE, in the eclipse of April, 1874. The small size of our photographs does not, indeed, allow us to fix the position of the axis within one or two degrees, but even then, allowing for this uncertainty, the symmetry is very striking. We have marked, as well as could be ascertained, the position of the sun's axis on Fig. 7, Plate ix. The similarity in the corona, as observed by us and by Mr. STONE just one year before, is exceedingly curious. The drawings given by Mr. STONE, in so far as they agree amongst themselves, agree with the corona observed at Siam. This similarity does not merely extend to the symmetry about

* The above outline woodcut has been made from the paper copies of the photographs published in the *Phil. Trans.* It has been oriented to correspond with the position of the sun's axis as marked by Messrs. Lockyer and Schuster on fig. 7, plate ix., of the *Phil. Trans.*

the sun's axis, but also to the irregularities in this symmetry. Thus the nearly straight boundary lines of the corona, which cut the axis at nearly right angles, are not quite parallel, but converge in both eclipses towards the east. The west side of the corona seems much more compact, the east side broken up into what the Siamese called fishtails. The similarity is, perhaps, most striking between Mr. Bright's drawing of the corona in 1874, and the drawing made by Prince Tong, by order of His Majesty the King of Siam, of the corona in 1875. The two drawings could certainly pass for representations of one and the same eclipse.

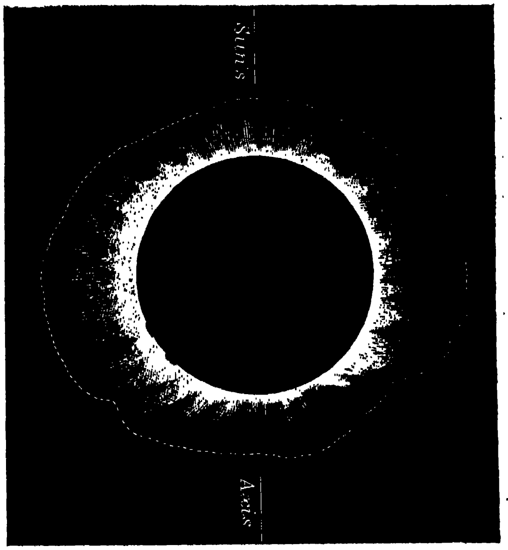
At the Observatory the Hon. H. N. Shore undertook to sketch the corona. . . . . .

The similarity between this sketch and Mr. Wright's of the corona in April, 1874, again, is very striking.

Eclipse of 1878, July 29th.

The accompanying woodcut is only intended to give a general idea of the corona which was visible during this eclipse. The details of the parts of the corona near to the sun's limb have been copied from my photographs taken near Denver. The higher parts of the structures are from copies of Dr. BRACKETT's photographs, and the dotted outline corresponds with the extent of the corona as shown on Dr. DRAPER's photograph.*

The orientation of the woodcut must be entirely disregarded, as the position of the sun's axis has not as yet been properly laid down upon the



Made from photographs of the corona of 1878, July 29th.

* Dr. HENRY DRAPER's photograph was taken at Rawlins, Wy. Terr., with a telescope of 5 inches aperture and 78 inches focal length, and an exposure of about 165 seconds; wet collodion plates and a neutral bath were made use of. On the copies of the photograph given me by Dr. Draper the corona does not extend in the equatorial regions to a height of a solar radius above the sun's limb.

Dr. BRACKETT's photographs were taken at Cherry Creek, near Denver, Colorado, with a 6-inch telescope of 7 feet 8 inches focal length, and exposures of 10, 15, and 25 seconds. The ordinary wet collodion process was made use of. In a letter dated Oct. 20th, 1878, Dr. Brackett writes, "With a scale divided to 40ths of an inch, I find the moon's diameter to be $\frac{34}{40}$ths of an inch. The greatest heights of the corona corresponding to different times of exposure run thus: 25 seconds = 13·75, 15 seconds = 6·75, 10 seconds = 5·5 fortieths respectively." That is to say, on the plate which was exposed for 25 seconds the corona extends to a height of just over 10′ above themoon's limb.

My photographs were taken at Cherry Creek, near Denver, with a camera of six feet two inches focal length, for the loan of which I am indebted to Mr. Esdaile. The lens has an aperture of 13 inches. One of the plates was exposed for about one second, the other for about three seconds. "Mawson and Swan's extra sensitive dry plates" were made use of. The corona does not extend to a height of 6′ above the sun's limb.

As far as my memory serves me, Dr. Brackett's negative, which was exposed for 25 seconds, was about as dense in its lower parts as Lord Lindsay's 1871 corona negatives; while Dr. Draper's negative, up to a height of 12′ or 13′, is decidedly denser; but I have not had an opportunity of

photographs. No groups of synclinal structure are recognizable, nor can any tree-like and branching structures be made out,* such as are visible upon the photographs of the corona taken during the eclipse of Dec. 1871. The separate details of the corona, however, seem to be more easily recognisable than on the 1871 photographs.

According to Dr. Wolf, the relative monthly number of sun spots for July, 1878, was only 3·3. It seems that the extent of the corona in the equatorial regions was much greater than in the polar regions, and that the great rays at the edges of the polar rifts were more nearly tangential than in the coronas of 1871 and 1875.

comparing the negatives side by side. Both Dr. Draper's and Dr. Brackett's photographs were taken with a perfectly cloudless sky. As seen from the camp at Cherry Creek, near Denver, the sun's altitude at mid-totality was 55° 16′; at Dr. Draper's station at Rawlins it was about 56°.

* Besides the photographs referred to on the last page, a valuable series of photographs of the corona was obtained by Prof. W. Harkness, at Creston, Wy. Terr. They were taken in the principal focus of a Dallmeyer portrait lens of 6 inches aperture and 37·90 inches focus. Mr. Rogers, of Washington Observatory, also obtained a very valuable series of photographs at another station with an instrument similar to that used by Prof. Harkness. Photographs were also taken by Mr. Waldo's party at Fort Worth, Texas. But none of these appear to show the tree-like structures or synclinal groups referred to above.

REFERENCE TABLE.

Date of Eclipse.	Angle of position of Sun's axis.	Dr. Wolf's relative monthly number of sun spots.	Date of Eclipse.	Angle of position of Sun's axis.	Dr. Wolf's relative monthly number of sun spots.
1715, May 1st, 21^h	335° 52′	*25·0	1867, Aug. 29th, 6^h	20° 35′	9·2
1766, Feb. 9th, 1^h	344° 4′	14·4	1868, Aug. 17th, 14^h	17° 20′	42·9
1806, June 16th, 4^h	350° 37′	29·6	1869, Aug. 7th, 11^h	13° 42′	77·6
1842, July 7th, 18^h	0° 30′	23·9	1870, Dec. 22nd, 0^h	6° 44′	135·4
1851, July 28th, 3^h	9° 23′	64·2	1871, Dec. 11th, 15^h	11° 40′	98·0
1853, Nov. 30th, 8^h	16° 13′	31·4	1874, April 16th, 2^h	333° 51′	49·1
1858, Sept. 7th, 2^h	22° 47′	64·3	1875, April 5th, 19^h	333° 30′	20·5
1860, July 18th, 3^h	5° 26′	94·9	1878, July 29th, 10^h	10° 4′	3·3

* In a letter dated Oct. 1879, Dr. Wolf writes : "Les observations solaires que je connais pour le mois de mai 1715 sont presque trop incertaines pour en dériver un nombre relatif. Mais je crois que le nombre 25·0 ne différera grandement du nombre effectif, et il me semble que pour le commencement du mois on pourrait même le porter à 35·0.

"Pour le mois de juillet 1878 le nombre relatif vrai ne s'élève qu'à 0·1, le nombre relatif compensé à 3·3."

The other relative numbers given in the above table are from Dr. Wolf's paper on sun-spot frequency published in Vol. xliii. of the *Memoirs*.

INDEX OF MANUSCRIPT AND PRINTED ACCOUNTS OF OBSERVATIONS OF SOLAR ECLIPSES WHICH HAVE BEEN REFERRED TO IN COMPILING THE PRESENT VOLUME.

WHERE there are several accounts of the observations made by any observer, together with letters, telegrams, newspaper announcements, and other printed matter referring to his observations, the documents have been, as far as possible, catalogued in the order of their date, placing manuscript matter before printed, and accounts of observations given by the observer himself before descriptions of his observations given by others.

In order to facilitate reference, we have distinguished different entries under one name by the Greek letters (α), (β), (γ), etc.; but unless dates are given, the order of arrangement must not be relied upon as indicating priority of publication.

When what appears to be the same name is spelt differently by different authors, or where one name occurs with materially different titles in different places, we have, except in the case of well-known observers, retained the various spellings and titles in the Catalogue.

Titles and letters denoting degrees and honours have been omitted unless they affect the name as usually referred to.*

Where the title given has changed since the date of the observation, the last or highest title (where known) has been made use of. †

The titles Mr. and Esq. have been omitted; but in the case of foreigners it has occasionally been found convenient to point out their nationality by the titles M., Herr, Sig., Don, etc.

Accounts of Observations of Eclipses up to A.D. 1836 *which have been made use of in the present Volume.* ‡

Cassini.—*See* MARALDI.

Cotes (Dr.)
Letter concerning observations of Eclipse of 22nd April, 1715, contained in "Correspondence of Newton and Cotes; edited by Edleston, from letters in Trin. Col. Library," at *p.* 181.
(*Two woodcuts of the Corona are given.*)
8vo, Cambridge, 1850.

Delisle.—*See* MARALDI.

Duillier (M. J. Chr.)
Abstract of a Letter from Geneva, May 31st, 1706, N. S., by M. J. Chr. Facio Duillier, to his brother, Mr. Nic. Facio, containing some observations of the Sun's Eclipse on the 12th of May, 1706, N.S.
Phil. Trans. for 1706, *p.* 22.

Dunbar (William).
Observations of the Eclipse of June 16th, 1806, made at Forest, near Natchez.
Trans. of the Amer. Phil. Society, 1*st Series, Vol.* vi., *pp.* 260—264.

* Thus the titles "Dr.," "Prof.," are given, while descriptions or titles, such as "Membre de l'Académie," "Director of Observatory," "Geheimrath," "Kriegsrath," "M.A.," "F.R.S.," "D.C.L.," "LL.D.," etc., which ordinary custom has not made a necessary part of the name, are omitted.

† *E.g.*, Admiral Richards at the time of his observation in 1860 was a Captain R.N. His name is given in the 1860 Catalogue as Richards (Admiral G. H.) This course has been adopted in order to avoid confusion, and because men are usually most widely known by the last title to which they attain.

‡ Up to A.D. 1836 the catalogue only refers to accounts of observations from which quotations have been made; after that date all accounts of observations which have been consulted are catalogued.

Ellicott (Andrew).
Observations of the Eclipse of the Sun, June 16th, 1806, made at Lancaster.
Trans. of the Amer. Phil. Society, 1st Series, Vol. vi., *pp.* 255—260.

Ferrer (Jose Joaquin de).
Observations of the Eclipse of June 16th, 1806, made at Kinderhook, in the State of New York.
Trans. of the Amer. Phil. Society, 1st Series, Vol. vi., *pp.* 264—276.

Flamsteed (Rev. John).
Mr. Flamsteed's Letter, concerning his observations and those of Mr. Townley and Mr. Halton, of the late Eclipse of the Sun, June 1st, 1676.
Hutton's Abridgment of the Phil. Trans., Vol. ii., *p.* 316.

Flamsteed (Rev. John).
Observations of the Solar Eclipse May 1—12, 1706, at the Royal Observatory at Greenwich. By the Rev. Mr. John Flamsteed, Math. Reg. and F.R.S.
Hutton's Abridgment of the Phil. Trans., Vol. v., *p.* 294.

Halley (Dr. Edmund).
Observations of the late total Eclipse of the Sun on the 22nd of April, last past; made before the Royal Society, at their house in Crane Court, Fleet Street, London.
Phil. Trans. for 1715, *pp.* 245-62.

De la Hire.—*See* MARALDI.

Le Gentil (M.)
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Arvedi, Dr.	Lordat, Prof.
Attenoux, M.	Magrini, Dr. Luigi.
Baily, Mr. Francis.	Majocchi, M.
Balaquer, Don Louis.	Massot, Dr.
Balsamo, Prof.	Mauvais, M.
Beau, M.	Mayette, Capt.
Billet, M.	Méryon, M.
Boisgiraud, M.	Nobile, M. Antoine.
Bouvard, M. Eugène.	Perigo, Prof.
Cabiati, Sig. Giambattista.	Petit, M.
Calvet, Don Esequiel.	Peytal, M. l'Abbé.
Cander, M.	Pinaud, M.
Casari, Prof.	Piris, Prof.
Cavana, Dr. Angelo.	Presas-y-Ping, Don Lorenzo
Dalbiez, M.	Regnaud, M.
dell'Acqua (Sig. Carlo).	Roche, M.
de Passa, M. Janbert.	Ruchinger, M.
Dieu, M.	Santini, M.
Fabre, M.	Savournin, M.
Farines, M.	Schaub, Prof. F.
Flangergues, Prof.	Schidlosfsky, M.
Fraisse, M.	Schumacher, M.
Fusinieri, M.	Selva, M.
Gonsalvo, M. François.	Struve, M. Otto.
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Huyn, Count.	Vieta, Dr.
Julia, Capt.	Vilaséca, M.
Kuhn, Lieut.	Wüllerstorff, M.
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Baily, Mr. Francis.	Majocchi, Prof.
Belli, Prof. J.	Mayer, Dr.
Berguis, Dr.	Mikocz, Prof. G. A.
Böhm, Dr.	Moser, Herr L.
Brestel, Dr.	Mück, Herr.
Carlini, Prof.	Pietropoli, Dr.
Casari, Prof. Lorenzo.	Pittel, Baron.
Colloredo-Wallsee, Count.	Reisinger, Prof.
Conti, Prof.	Santini, Prof.
von Elgg, Dr. O. W.	Schaub, Prof. F.
Gallo, Prof.	Schumacher, Prof.
Hallaschka, Prof.	Semenzi, Sig. G. B. Alvise.
Hänsler, Lieut.	Stark, Herr.
Heider, Dr. M.	Steinheil, Herr.
Jüttner, Herr.	Wissiak, Lieut.
Keserü, Herr.	von Wullerstorf, Lieut.
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Vol. i. *of MS. Reports of the Himalaya Expedition.*
(β) Éclipse totale de Soleil du 18 juillet, 1860, observée à Lambessa, province de Constantine.
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(α) Observation de l'éclipse totale du Soleil du 18 juillet, 1860.
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(β) *See* LESPIAULT.
(γ) *See* MÄDLER (α).
(δ) *See* MÄDLER (β).

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(α) Letters to the Astronomer Royal, and MS. papers referring to Mr. De La Rue's observations, with paper copies of two of his negatives.
Vol. i. *of MS. Reports of the Himalaya Expedition.*
(β) Letter to the Editor of the *Times.*
The Times, 9th Aug., 1860.
(γ) Letter to the Editor of the *Illustrated London News*, describing observations at Miranda del Ebro. Illustrated by picture of photographic hut, with instruments and observers, two woodcuts of the photographs, and a diagram showing the relative position of the prominences.
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(β) *Heis. W. S.* 1860, *pp.* 336-8.
(γ) Remarques sur les observations de MM. D'Abbadie et Von Feilitzch.
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(ε) *Cosmos*, xvii., *pp.* 758 61.
(ζ) *Inst.* 1861, *pp.* 5, 6.

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(β) Éclipse solaire du 18 juillet. Indication des faits observés à Castellon de la Plana (royaume de Valence, Espagne). Lettre de M. Faye à M. le Secrétaire perpétuel.
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(α) Letters addressed to the Astronomer Royal referring to observations of the Eclipse at Steilacoom, together with a drawing and MS. account of observations.
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Mr. H. A. Goldsborough, *p.* 15.
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(δ) Observations de l'éclipse de Soleil du 18 juillet (Vittoria).
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Vol. ii. *of MS. Reports of the Himalaya Expedition.*

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(α) MS. account of observations made at Peña Cerrada, near Logroño.
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(β) Notes on the Total Eclipse of the Sun of July 18th, 1860, observed in Spain.
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(β) Ueber die Beobachtungen der Sonnenfinsterniss vom 18 Juli, 1860, in Spanien.
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(γ) *See* MÄDLER (β).

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(α) Sur les protubérances rouges observées pendant l'éclipse de Soleil du 18 juillet, 1860.
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(α) Observation de l'éclipse du 18 juillet : extrait d'une lettre.
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(γ) *See* MÄDLER (β).

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(β) Observations faites à Briviesca (Vieille-Castille).
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(δ) *See* MÄDLER (β).

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Lowe (E. J.)
(α) MS. account of a very complete series of meteorological observations made at Fuente del Mar, near Santander. (A folio volume of 25 pages of observations and diagrams, showing, by means of curves, the temperature at various heights above and below the ground, the amount of cloud, and the photographic action of light, etc., etc., during the progress of the eclipse.)
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(β) Letter to the Editor of the *Times*, describing meteorological and other observations made in Spain during the Eclipse of July 18th, 1860.
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The foregoing contains observations by

Aguilar, Don Antonio, 26-7.	Mayo, M., 29, 30.
Arndt, Herr, 39.	Monserrat, M., 27.
Barreda, M., 28.	Otaño, Prof., 41.
Bianchi, Herr, 20, 21.	Pake, Mr. Charles, 34-5.
Bottella, Don, 28-9.	Petit, M., 41.
Bruhns, Dr., 35-6.	Plantamour, Prof., 40.
Burat, Prof., 42-3.	Prazmowsky, M., 41-2.
Chacornac, M., 33-4.	Rennenkampff, Herr G. V., 17, 18.
Cuillier, M., 20, 21.	Roure, Don Geronimo, 22-3.
De La Rue, Mr. W., 45-6.	Saar, Martin, 12, 13.
Feilitzsch, Prof. Freiherr, 38-9.	Schulz, Herr C., jun., 16, 17.
Foucault, M. Leon, 36-7.	Schulz, Herr G., 15, 16.
deGaraganza, Eugenio, 22-3.	Secchi, Padre A., 30-32.
Goldschmidt, M. Hermann, 18-20.	Villarceau, M. Yvon, 37-8.
LeVerrier, M., 37.	Wallenberg, Herr C. von, 44.
Mädler, Dr. J. H. von, 10-12.	Weyer, Prof., 13-15.
Mädler, Frau von, 24-6.	Zabala, Dr. Pedro Vicente, 23-4.

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Alexander, Prof., 29, 30.	Laussedat, Prof., 26.
Auerbach, Herr, 16-18.	Lespiault, Prof., 14, 15.
Bey, Mahmoud, 1.	Marquez, Don Francisco de Paula, 20.
Bruhns, Dr., 16-18.	Rumker, Prof. Geo., 12.
Burat, Prof., 14, 15.	Stenglein, Herrn, 12.
Haase, Herr C., 19, 20.	Thiele, Dr. Th. N., 25-6.
Klenkerfues, Dr., 16.	

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Über Totale, etc.

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(α) Rapport à Son Altesse le vice-roi d'Égypte sur l'éclipse totale du 18 juillet, observé à Dongolah.

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(β) *See* MÄDLER (β).

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(α) Franges mobiles incolores observées pendant l'éclipse du Soleil du 18 juillet, 1860.

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(β) *See* LAUSSEDAT.

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(α) Memoria sobre el Eclipse de Sol de 18 de Julio, 1860, par D. Francisco de Paula Marquez, director del Osservatorio de Marina de S. Fernando.

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(β) *See* MÄDLER (β).

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A. R. 4*to*, *pp.* 12 : *Roma*, 1860.

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Vol. ii. *of MS. Reports of the Himalaya Expedition.*

Maxwell-Lyte (F.)

(α) Letter to the Astronomer Royal describing observations made from the Hotellerie of the Pic du Midi, and containing paper copies of seven photographs of the partial phases made with a camera 5½ metres long.

Vol. iv. *of MS. Reports of the Himalaya Expedition.*

(β) *See* FARNAM.

Mayo.—*See* MÄDLER (α).

McTaggart (Dr.)

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Michelier.—*See* FARNAM.

Möller (Dr. Axel).

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(β) Berättelse om en med auslag af allmänna medel företagen resa, för att i det inre af Spanien observera den totala solförniörhelsen af den 18 Juli, 1860. Af Axel Möller, Astronomie Observator vid Universitetet i Lund.

Monserrat.—*See* MÄDLER (α).

Morley (S.)—*See* LOWE (E. J.)

Mosman (A. T.)

Observations made near Steilacoom.

Coast Survey Report for 1860, *Appendix* xxii., *p.* 14.

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Vol. ii. *of MS. Reports of the Himalaya Expedition.*

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Oom (Lieut. F. A.)

(α) MS. account of observations made at Alto d'Urbaneja, near Pobes.

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(β) *See* STRUVE.

Otaño (Prof.)—*See* MÄDLER (α).

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(α) Letter to the Editor of the *Times* on his observations of the Eclipse of July 18th, 1860, made on the Pic de Moncayo, Spain.

The Times, July 26th, 1860.

(β) *See* MÄDLER (α).

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Vol. ii. *of MS. Reports of the Himalaya Expedition.*

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MS. account of observations made at Ali, near Vittoria.
Vol. ii. of *MS. Reports of the Himalaya Expedition.*

Perry (J. G.)
MS. account of observations made at Cantabria, one mile from Logroño.
Vol. ii. *of MS. Reports of the Himalaya Expedition.*

Petit (F.)
(α) Observations de l'éclipse du 18 juillet, faites à Briviesca. Lettre à M. Elie de Beaumond.
Comptes Rendus, li., *pp.* 389-94.
(β) Beobachtung der totalen Sonnenfinsterniss, 1860, Juli 18.
Astr. Nachr., *Vol.* liv., *pp.* 75—80.
(γ) Schreiben des Herrn Petit an den Herausgeber (Table of times of totality).
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(δ) Observations de l'éclipse du 18 juillet, faites à Briviesca.
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(ε) *See* MÄDLER (α).

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(α) Observation de l'éclipse totale de Soleil du 18 juillet, 1860, à Castellon de la Plana (Espagne).
A. R. *Reprinted from "Les Archives des Sciences de la Bibliothèque Universelle"*: *8vo, Genève*, 1860, *pp.* 12 (three plates).
(β) *See* MÄDLER (α).

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(α) MS. account of observations made at La Cantabria, near Logroño.
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(β) Narrative of the Astronomical Expedition to Spain for observing the Total Eclipse, etc.
A. R. *8vo, London*, 1860, *pp.* 13. *A Reprint from "Macmillan's Magazine" for Sept.* 1860.

Prazmowski (M.)
(α) Observation de l'éclipse totale de Soleil du 18 juillet, 1860.
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(β) Causes des rayons courtes de la couronne des éclipses solaires.
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(γ) *See* MÄDLER (α).

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Monthly Notices, xxi., *p.* 23.

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Bilbao, Spain.
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A. R. *Extrait des Bulletins de l'Académie R. d. Bruxelles*, 2e *série*, *tom.* x., *No.* 8.

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Fyers, Capt., 31.	Sharp, The Rev. John, 21-2.
Grinlinton, Mr., 31.	Walker, Mr. C. G., 15-19.
Iyengar, C. Appoo, 26.	Winter, Mr. G. K., 19-21.
Levinge, Mr. V. H., 30.	Worster, Colonel W. K. 27-8.
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Addison, Col. J., 22-3.
Beale, Lieut. B., 24-5.
Blurton, Capt., 24-5.
Branfill, Capt., 48-58.
Campbell, Lieut. W. R., 35-7
Chary, C. Ragoonatha, 45-6.
Commijs, J. C., 98-9.
Ehnle, E. L., 97-8.
Fauro, Padre Federico, 99-105.
Haigh, Capt. C. T., 38-41.
Heeckeren, Capt. C. A. L. H., 105-6.
Hennessy, J. Pope, 87-91.
Herschel, Lieut. J., 32-5.
Janssen, M., 58-62.
King, Capt. Hy. Welchmann, 73-4.
Laxuman, Prof. Kers, 38-41.
Macdonald, J., 62-4.
Oppolzer, Dr. Th., 13-19.
Oudemans, Dr. J. A. C., 93-7.
Pogson, Mr. N. R., 64-9.
Rapatel, M., 74-5.
Rennoldson, Capt. D., 30-1.
Rziha, Linienschiffsfähnrich J., 20-22.
Schuylenburg, Lieut. C., 91-2.
Sharp, J., 72-3.
Spoerer, Prof., 42-3.
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Tanner, Capt., 38-41.
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(γ) On his Photographs taken during the Total Solar Eclipse, Aug. 7, 1869.
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(γ) Account of the Agosta Eclipse Expedition.
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(β) Article on the Eclipse Expedition.
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(β) Article on the Solar Eclipse, from our special correspondent.
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(α) Photographic views of the Eclipse as seen in London.
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(β) Article entitled "The Eclipse at Gibraltar," with a woodcut of the corona as seen through a telescope.
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Hostage (J.)
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(α) MS. account of observation and drawing of the corona made at San Antonio, Spain.
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Coban, Prof. Luigi.	Muller, Com^re, D. E. Diamilla.
Costantino, Giuseppe.	Nobile, Prof. A.
Cultera, Prof.	Perrero, Cav. Buffa di.
De Lisa, Giuseppe.	Secchi, Prof. Padre Angelo.
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(α) Telegram sent to the Astronomer Royal announcing the results of the Eclipse observations at Maria Louisa, near Cadiz.
Nature, *Vol.* iii., *p.* 171.

(β) Ten drawings made by Lord Lindsay's party stationed at the Maria Louisa Observatory, between San Lucar and Jerez.
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Lockyer (J. Norman).
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Nature, *Vol.* iii., *p.* 171.

(β) Article entitled "The Mediterranean Eclipse, 1870."
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(γ) Second article entitled "The Mediterranean Eclipse, 1870" (small woodcut of Gillman's corona drawing).
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(δ) Lecture delivered at the Royal Institution on the Eclipse of 1870.
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(β) Paragraph entitled "The Sicilian Eclipse Expedition," containing a letter from Mr. Brothers.
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(γ) Article on the loss of Her Majesty's Ship *Psyche*.
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(δ) Article on the Recent Solar Eclipse.
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(α) Telegrams announcing the results of his eclipse observations.
Nature, Vol. v., *pp.* 150 *and* 190.

(β) Rapport à l'Académie relatif a l'observation de l'éclipse du 12 décembre, 1871, observée à Shoolor (Indoustan).
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(γ) Lettre de M. Janssen à M. le Secrétaire perpétuel de l'Académie.
Comptes Rendus, lxxiv., *pp.* 107-11.

(δ) Lettre sur les conséquences principales qu'il peut, dès aujourd'hui, tirer de ces observations sur l'éclipse de décembre dernier.
Comptes Rendus, lxxiv., *pp.* 185-6.

(ε) Lettre adressé à M. le Secrétaire perpétuel.
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(ζ) Letter from M. Janssen to the President of the Royal Astronomical Society.
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(α) Article on the Eclipse Expedition in India, with two woodcuts: 1. "The Astronomers waiting for the Eclipse;" 2. "The Astronomers' Bungalow at Békul."
Illustrated London News, 20th Jan., 1872.

(β) Short paragraph, "The Eclipse Expedition in India," with large woodcut called "Sketch at Baikul."
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(γ) Letter (dated Ootacamund) describing his observations of the recent Eclipse.
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(δ) Article on "The Solar Eclipse."
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(ε) Ad interim report on the results obtained by the British Association Eclipse Expedition of 1871.
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(ζ) Lecture delivered at the Royal Institution on the Eclipse Expedition of 1871.
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Maclear (Commander J. P.)

(α) Letter from Ceylon on the arrangements for the Expedition.
Nature, Vol. v., *p.* 163.

(β) MS. account of spectroscopic observations made at Békul.
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(γ) Letter dated Jan. 6, 1872, describing his observations of the recent Eclipse.
Nature, Vol. v., *pp.* 219-21.

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Observer Press, Colombo, 1872.

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(α) Telegram from, announcing the results of his observations.
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Mr. Bergsma.	Mr. Lang.
Prof. Oudemans.	Dr. Scheffer.

Paige (G. H.) (?)
MS. account of observations (no place given).
MS. Reports of the 1871 *Eclipse Expedition.*

Perry (Rev. S. J.)
Magnetic disturbances during the late Total Eclipse.
Nature, Vol. v., *p.* 269.

Pillay (T. Gopalkristnah).

Annappa (O.)
MS. account of observations and drawings made at Mangalore.
MS. Reports of the 1871 *Eclipse Expedition.*

Pogson (Mr. N. R.)
Telegram to the Astronomer Royal announcing the results of his eclipse observations.
Nature, Vol. v., *p.* 130.

Pringle (E. H.)
Drawing of a portion of the corona seen through the finder of a six-inch refractor.
MS. Reports of the 1871 *Eclipse Expedition.*

Ragoonatha Chary (C.)
On the Total Eclipse of the Sun on Dec. 11th, 1871, as visible in the Madras Presidency.
Extracted from the Monthly Notices, Vol. xxxi., *pp.* 137-46.

Respighi (Prof. L.)
(α) MS. account (*in French*) of spectroscopic observations made at Poodoocottah.
MS. Reports of the 1871 *Eclipse Expedition.*
(β) Account of his observations made at Poodoocottah.
Nature, Vol. v., *pp.* 237-8.
(γ) Osservazione dell' Eclisse Totale del 12 Dec., 1871, a Poodoocottah nell' Indostan.
(Estratta dagl' atti della Reale Accademia de' Lincei, sessione 4ª, dell 3 Marzo 1872.)
4to, Rome, 1872, *pp.* 23 (one folding plate).

Ranyard (A. Cowper).
On a remarkable structure visible upon the photographs of the Eclipse of Dec. 12, 1871.
Monthly Notices, xxxiv., *p.* 365.

Rickard (F. M.)
MS. account of observations made in India (no place given).
MS. Reports of the 1871 *Eclipse Expedition.*

Rosario (P. C.)
MS. account of observations made at Mangalore.
MS. Reports of the 1871 *Eclipse Expedition.*

Rum Rao (Raja).
MS. account of observations made at Baikul.
MS. Reports of the 1871 *Eclipse Expedition.*

Russell (H. O.)
Eclipse of December last, Australian Expedition.
Monthly Notices, xxxii., *pp.* 220-21.

Saxton (Col. G. H.)
See TENNANT (LIEUT.-COL. J. F.) (δ)

Scheffer (Dr.)
See OUDEMANS (PROF.)

Secchi (Padre Angelo).
Sull' ultima Eclisse del 12 Dicembre, 1871.
(Estratto dágli atti dell' Accademia Pontificia de nuovi Lincei, anno xxv., sessione 3ª del 18 Feb., 1872.)
4to, Rome, 1872, *pp.* 20 (one lithographic plate).

Selby (General).
MS. account of observations, and two drawings of the corona, made at Baikul. Observations of eclipse of 1871, Dec. 12.
MS. Reports of the 1871 *Eclipse Expedition.*

Taxendle (W.) (?)
MS. account of observations (no place given).
MS. Reports of the 1871 *Eclipse Expedition.*

Tebbutt (John).
The Solar Eclipse of December 12th, 1871.
Monthly Notices, xxxii., *pp.* 243-4.

Tennant (Lieut.-Col. J. T.)
(α) Telegram to Dr. Huggins announcing the results of his eclipse observations.
Nature, Vol. v., *p.* 130.
(β) Letter from Col. Tennant to Dr. Huggins.
Monthly Notices, xxxii., *pp.* 70-72.
(γ) Report on observations made by the Government of India on the Total Eclipse of Dec. 11-12, 1871 (abstract).
Monthly Notices, xxxii., *pp.* 253-4.
(δ) Report of observations made by order of the Government of India on Dec. 11-12, 1871, at Dodabetta, near Ootacamund.
Fol., 23 *pp.* (illustrated with photographs), *Calcutta,* 1872.

The above contains accounts of observations by

Broughton, Mr. J.	Morant, Capt.
Hennessey, Mr. J. B. N.	Saxton, Col. G. H.
Herschel, Capt. J.	Waterhouse, Capt.

(ε) Report on observations of the Total Eclipse of the Sun on Dec. 11-12, 1871, made by order of the Government of India, at Dodabetta, near Ootacamund.
(This is a reprint of (δ) with additions.)
Memoirs of the R.A.S., Vol. xlii., *pp.* 1-32, (with two quarto mezzotint steel plates made from negatives 1, 2, 3, and 4 of the Dodabetta series of photographs).

Tupman (Capt. G. Lyon).
MS. account of observations made at Jaffna.
MS. Reports of the 1871 *Eclipse Expedition.*

Walhouse (J.)
MS. account of observations made in India (no place given).
MS. Reports of the 1871 *Eclipse Expedition.*

Waterhouse (Capt.)
See TENNANT (LIEUT.-COL. J. F.) (δ)

Winter (G. K.)
Letter to the editor of *Nature*, entitled "Radial Polarization of the Corona."
Nature, Vol. vi., *p.* 371.

Annular Eclipse of 1872, *June* 6.

Nursinga Row (Ankitam Venkata).
Observations made during the Eclipse of June of 1872.
Monthly Notices, xxxii., *pp.* 329-30.

Pogson (N. R.)
Observations made during the Eclipse of June 6, 1872 (from a letter to the Astronomer Royal).
Monthly Notices, xxxii., *pp.* 330-31.

Total Eclipse of 1874, *April* 16.

Barnabita (Padre F. Denza).
Osservazioni della Declinazione Magnetica fatte in occasione della Eclisse di Sole del 9-10 Oct., 1874, del Aprile a del 29 Settembre, 1875.
(Estratto dagli atti dell Accademia Pontificia de Nuovi Lincei, ann. xxix., ses. 7ª, 18 July, 1876.)
4to, pp. 42 (three plates), *Rome*, 1876.

Stone (E. J.)
(α) Observations of the Total Solar Eclipse of April 16, 1874, at Klipfontein, Namaqualand, South Africa.
(Extract from a letter to the Astronomer Royal.)
Monthly Notices, xxxiv., *pp.* 399-401.
(β) The Total Eclipse of the Sun, 1874, April 16.
Mem. R. Astr. Soc., xlii., *pp.* 35-57 (one lithographic plate).

The above contains accounts of observations by

Bright, Mr. H. E. R.	Hall, Mr. Henry.
Degerman, Mr.	Orpen, Mr. F. H. S.
Hall, Miss Alice.	Stone, Mrs.

Total Eclipse of 1875, *April* 6.

Lockyer (J. Norman).

Schuster (Arthur).
Report on the Total Solar Eclipse of April 6, 1875. (Illustrated by five plates and paper prints from enlarged copies of photographs of the corona).
Phil. Trans. for 1878, *Vol.* clxix., *Pt.* i., *pp.* 139-154.

The above contains accounts of observations by

Beasley, Mr. Frederick.	Mendola, Mr. R.
Chetochereur, Prince.	Ord, Sir Harry St. George.
Devanndaywongse, Prince.	Reynolds, Mr. J.
The King of Siam.	Schuster, Dr. A.
Lott, Mr. Frank Edward.	Shore, The Hon. H. N.
Maha Mala, H.R.H. Chau Fa.	Tong, Prince.

ALPHABETICAL LIST OF PLACES OF OBSERVATION.

The following list of observing stations and observers is far from complete; but it will, no doubt, be useful to the reader in comparing and weighing observations.

Where the latitude and longitude of an observing station have been specially determined, the name of the observer by whom the determination has been made is given in brackets.

Aci Reale, 1870. Observers on board H.M.S. *Caledonia.*

Bennett, Mr. E. J. — Bridge, Commander A. S.

Aden (*Marshag Hill*), 1868. 12° 45′ 47.1″ N. 45° 2′ 55″ E. [Dr. Oppolzer.]

Beale, Lieut. — Tiele, Dr. B.
Blurton, Capt. — Vogel, Dr H.
Fritsch, Herr G. — Weiss, Dr. Edmund.
Oppolzer, Dr. Theodor. — Zenker, Dr. W.
Riha, Linienschiffsfahnriches, J.

Agosta.—*See* **Augusta.**

Ali, *near Vittoria,* 1860. 42° 50′ N. 2° 40′ W.

Churton, The Rev. T. T. — Perowne, The Rev. J. J. S.
Churton, Mrs. — Petel, M. Olindo.
Goodwin, The Rev. H. A.

Alto d' Urbaneja, *near Pobes,* 1860. 42° 46′ 44″ N. 2° 53′ 22″ W.

Oom, Lieut. F. A.

Amurrio, 1860. 43° 4′ N. 2° 58′ W.

Croudace, Mr. T. V. — Vignoles, Mr. C. J.
Shoolbred, Mr. J. N. — Vignoles, Mr. Henry.

Argos, 1870. 41° 10′ N. 2° 17′ W. Sometimes written **Arcos.**

Gillman, Mr. — Smyth, Mr. Warrington.
McPherson, Mr.

Ardwick, *near Manchester,* 1870. 53° 28′ 21·75″ N. 2° 13′ 11″ W.

Dancer, Mr. J. B.

Areta.—*See* **Arrana Monte.**

Arrana Monte, *near Llodio,* 1860. 43° 10′ N. 2° 50′ W. On Mr. Vignoles' map written **Areta.**

Stronglein, Mr. John.

Augusta, 1870. 37° 14′ 20·5″ N. 15° 13′ E. Sometimes spelt **Agosta.**

English Encampment.

Adams, Prof. W. G. — Clifford, Prof. W. K.
Bell, Sergeant John. — Garam, Sergeant Wm.
Brett, Mr. J. — Jarvis, Sergeant John.
Buchanan, Sergeant Alex. — Muir, Sergeant James.
Burgoyne, Sergeant. — Porter, Colonel.
Burn, Sergeant James. — Ring, Sergeant.
Burton, Mr. C. E. — Shepherd, Sergeant Wm.
Campell, Corporal.

Italian Observers' Station, Castello di Augusta.

Blaserna, Prof. Pietro. — Denza, Padre Francesco.
Caccialore, Prof. G. — Donati, Prof. G. B.
Corallo, Sig. Arciprete. — Pistoia, Capt.
Cultrera, Prof. — Secchi, Padre Angelo.
De-Lisa, Dr. G.

Aulezavik Island, 1860. 59° 47′ 49″ N. 64° 7′ 15″ W. Ungava Bay [Ashe].

Ashe, Lieut. E. D. — Smith, Prof. A. W.
Barnard, Dr. F. A. P. — Venable, Prof. C. S.
Nones, Mr. H. B.

Avenashy, 1871. 11° 11′ N. 77° 19′ E. Sometimes spelt **Avinasi.**

Pogson, Mr. N. R.

Avola, 1870. 36° 54′ N. 15° 8′ E.

Frisiani, Prof.

Baikul.—*See* **Békul.**

Banderas, *near Bilboa,* 1860. 43° 10′ N. 2° 50′ W.

Mantesino, Sig.

Bardstown, (*Kentucky*) 1869. 37° 50′ N. 85° 23′ W.

Peirce, Prof. Charles. — Smith, Prof. J. Laurence
Shaler, Mr. N. S.

Barram Point (*Borneo*), 1868. 4° 35′ N. 113° 55′ E.

Doyley, Mr.
Ellis, Lieut.
Hennessy, Governor Pope.
O'Connor, Dr.
Petley, Mr.
Ray, Lieut.
Reed, Capt.
Roughton, Mr.
Wright, Mr.

Batavia, 1871. } 6° 11′ 0″ S. 106° 49′ 45″ E.

Bergsma, M.

Batna, 1860. { 35° 32′ 50″ N. 6° 10′ 30″ E. } [M. Laussedat.]

Bour, M.
Girard, M.
Laussedat, M. A.
Mannheim, M.
Salicio, M.

Bath, 1861. } 51° 24′ N. 2° 21′ W.

Hardy, Mr. R. W. H.

Beaune, 1851. } 47° 1′ N. 4° 52′ E.

Lion, M.

Beijapoor, 1868. { 16° 50′ N. 75° 48′ E. } Sometimes called **Bijapoor.**

Chatrey, Prof. Keru Luximon.
Haig, Capt. C. T.
Tanner, Capt.

Békul, 1871. { 12° 25′ N. 75° 0′ 6″ E. } Sometimes written **Baikul.**

Baily, Capt.
Cherry, Mr.
Christie, Capt.
Davis, Mr. H.
Farewell, Colonel.
Lockyer, Mr. J. Norman.
Maclear, Commander.
McIvor, Mr.
Pringle, Mr. E. H.
Rum Rao, Raja.
Selby, General.
Thomson, Dr.
Walhouse, Mr.

Belfort, 1860. } 47° 36′ N. 6° 52′ E.

Vernier, M.

Besançon, 1851. } 47° 13′ N. 6° 2′ E.

Sire, M.

Bezana, 1860. } 42° 58′ 11·6″ N. 3° 54′ W.

Fearnley, Prof. C.
Lindelöf, Dr.
Lindhagen, Dr.

Bezwarra, 1868. { 16° 21.2′ N. 80° 43′ 15″ W. } [Weiss.]

Macdonald, Major J.

Bilbao, 1860. } 43° 15′ 30″ N. 2° 55′ 7″ W.

Gaudi, M. Charles.
Lewis, Mr. W. J.
Professors of the Viscayan Institute.

Bintensorg (*Java*), 1871. } 6° 35′ 45″ S. 106° 47′ 22″ E.

Lang, Mr.
Scheffer, Dr.

Bishop's Observatory (*London*), 1860.

Hind, Mr. J. R.

Bloomington, 1869. } 39° 45′ N. 92° 43′ W.

Jackman, Mr. John A.
Pierce, Mr. J. M.
Warner, Mr. Joseph B.

Bombay (*near*), 7 Oct., 1847. } 18° 56′ 14″ N. 72° 52′ 0·7″ E.

Jacob, Captain.

Boonesboro', Yoone County, Iowa, 1869. } 42° 3·4′ N. 76° 21′ 30″ W.

Paine, Mr. R. T.

Brentwood (*Essex*), March, 1858. } 51° 37′ N. 0° 12′ E.

Smyth, Prof. C. Piazzi.

Bristol (*Tennessee*), 1869. } 36° 35′ 49·10″. 82° 11′ 13″.

Allen, Mr. Charles J.
Cutts, General Richard D.
Mosman, Mr.
Perkins, Mr. F. W.
Walthall, Mr. Thomas D.

Briviesca, 1860. } 42° 33·3′ N. 3° 20′ W.

d'Abbadie, M. Antoine.
Burat, M.
Lespiault, M.
Otano, M.
Petit, M.
Prazmowski, M.
Rechienski, M.

Bruxelles, 1860. } 50° 51′ N. 4° 21′ E.

Quetelet, Prof. E.

Bue, Island of, 1851. } 61° 9′ 42″ N. 4° 21′ E.

Anderson, Capt.
Robinson, Dr.
Smyth, Prof. Piazzi.
Stephenson, Mr. Alan.
Urquhart, Mr. Commissioner.

Burgos, 1860. } 42° 21′ N. 3° 43′ W.

Janson, Mr. T. C.

Burlington, 1869. } 40° 48′ 17″ N. 91° 4′ W.

Gould, Dr. B. A.
Kendall, Mr. O. H.
Mahoney, Mr. J.
Mayer, Prof. A. M.
Phillips, Mr. H. C.
Rock, Mr. Miles.
Willard, Mr. O. H.
Young, Prof. C. A.

Cadiz, 1870. } *See* **San Antonio.**

Calmar, 1851. } 56° 40′ N. 16° 20′ E.

Olufsen, Prof.

Cammesa, 1860. } 42° 46′ N. 4° 12′ W.

Breen, Mr.
Buckingham, Mr. J.
Wray, Mr. Wm.

Cantabria, Hill of, *near Logrono,* 1860. } 42° 27′ N. 2° 30′ W.

Perry, Mr. J. G. Pole, Prof. William.

Carlentini (*Sicily*), 1870. } 37° 14′ N. 15° 1′ E.

Watson, Prof. J. C.

Carlsten, 1851. } 57° 53′ 47″ N. 12° 51′ E.

Agardh, Herr J. M.

Castellon de la Plana, 1860. } 39° 57′ N. 0° 4′ W.

In a garden near the Town and by the Sea.

Arndt, Herr. Lamont, Dr. J.
Bremiker, Dr. C.

In the Tower of the Cathedral.

Feilitzsch, Baron von. Rümker, Herr G.
Legrand, M. J. N. Wolff, M.

Convent of San Francisco.

Plantamour, Prof.

Catania, 1870. } 37° 30′ 13·4″ N. 15° 5′ 23″ E.

English Party.

Cumming, Mr. Seabroke, Mr.
Lockyer, Mr. J. Norman. Thorpe, Dr.
Lockyer, Mrs. Vignoles, sen., Mr.
Pedler, Mr. Vignoles, jun., Mr.

American Party.

Lane, Prof. J. Homer. Schott, Prof. Chas. A.

Catania (*near*), 1870. } San Giuliano Villa.

Peirce, Prof. Chas. S. Peirce, Mrs. Chas. S.

Cedar Falls, Iowa, 1869. } 42° 32′ 32·3″ N. 92° 26′ 42″ W.

Anderson, Mr. W. J. Stanley, Mr. J. H.
Horr, Dr. Asa. Wormold, Mr. W. W.
Horr, Mr. E. W.

Cherokee, Iowa, 1869. } 42° 46′ 26″ N. 95° 38′ W.

Blickensderfer, jun., Mr. J.

Cherry Creek, *near Denver, Colorado,* 1878.

Prof. Young's Party.

Anderson, Mr. McNeill, Mr.
Bennett, Mr. Ranyard, Mr. A. C.
Brackett, Dr. Rockwood, Prof.
Brackett, Mrs. Smith, Mr.
Calley, Mr. Young, Prof. C. A.
Libbey, Mr. Young, jun., Mr. C.
McDonald, Mr.

Christiania, 1851. } 59° 54′ 5″ N. 10° 43′ 28″ E.

Bennett, Mr. Raon, Lieut.
Dunkin, Mr. E. Snow, Mr. Robert.
Langberg, Prof.

Christianstadt, 1851. } 56 4′ N. 14° 10′ E.

Humphreys, Mr. George. Silverstolpe, Colonel.
Miland, Mr. John.

Colchagua, 1867. } Name of a Farm near Santiago.

Grosch, Herr L. Vidal, Lieut.
Vergara, Herr.

Cremano (*near Naples*), 1851.

Dembowski, Baron H.

Dantzig, 28 July, 1851. } 54° 20′ 58″ N. 18° 40′ 15″ E.

Goujon, M. Mauvais, M.

Denver (*Capitol Hill, near*), 1878. } 39° 44′ 20″ N. [Hough.] $1^h\ 54^m\ 48{\cdot}3^s$ W. of Washington.

Colbert, Prof. Elias. Hough, Prof. G. W.
Easterday, Prof. Swift, Prof. Lewis.
Hale, Prof. Thomas, Mr. Alfred C.

Denver, 1878.

Hubbard, Mr. Cyril. Loder, Mrs.
Loder, Mr. Edmund.

Denver (*near*), 1878.

Penrose, Mr. F. Cranmer.

Denver (*near*), 1878.

Miss Mitchell's Party.

Abbott, Miss E. O. Kendall, Miss P. M.
Culbertson, Miss E. Marsh, Miss C. W.
Harrison, Miss C. Mitchell, Miss Maria.

Desierto de las Palmas 1860. } 40° 5′ N. 0° 0′

Aguilar, Don Antonio. Cepeda, M.
d'Aguilar, Sig. Gaetano. Monpensier, Duke of.
Alcover, Sig. Monserrat, Prof.
Barreda, Prof. Secchi, Padre A.
Botella, Sig. Venader, Prof.

Des Moines, 1869. } 41° 35′ 32″ N. 93° 37′ 15″ W.

Prof. Harkness' Station.

Brennan. Harkness, Prof. Wm.
Curtis, Dr. Le Merle, Mr. A. E.
Eastman, Prof. J. R.

Des Moines, 1869. } 41° 35′ 02·69″ N. 93° 37′ 17″ W.

Prof. Hilgard's Station.

Cecil, Lord Sackville Arthur. Hilgard, Dr. T. C.
Goodfellow, Mr. Edward. Lane, Mr. J. Homer.
Hilgard, Prof. J. E.

Des Moines, 1869. — 41° 35′ 4″ N., 93° 37′ 12″ W.

Prof. Simon Newcomb's Station.

Armstrong, Mr. — Newcomb, Prof. Simon. — Fraser, Prof. John.

Digne, 1842. — 44° 5′ N., 6° 15′ E.

Bouvard, M. Eugène.

Dodabetta, 1871. — 11° 24′ N., 76° 43′ E.

Broughton, Mr. J. — Saxton, Colonel. — Hennessey, Mr. J. B. N. — Tennant, Lieut.-Col. J. F. — Morant, Capt. — Waterhouse, Capt.

Dongolah (*Nubia*), 1860. — 19° 12′ 41″ N., 28° 0′ 30″ E.

Bey, Mahmoud. — Al-Soubki, Ahmed-Effendi-. — Ibrahim, Hussein-Effendi-.

Dröbah, 1851. — 59° 40′ N., 10° 37′ E.

Biddulph, Captain.

Erena (*Hill above*), 1860. — *See* Hereña.

Estepona, 1870. — 36° 25′ N., 5° 8′ W.

Anson, Mr. J. H. — Fison, Mr. F. W. — Beasley, Mr. — Gordon, Mr. J. E. H. — Buckingham, Mr. J. — Lewis, Mr. W. J. — Carpmael, Mr. Chas.

Etna, 1870. — 37° 37′ N., 15° 5′ E.

Abbott, General Henry L. — Peters, Dr. C. H. F. — Bowen, Mr. E. E. — Roscoe, Prof. H. E. — Darwin, Mr. Geo. H. — Silvestri, Prof. — Harris, Mr. — Vogel, Dr.

Falmouth (*Kentucky*), 1869. — 38° 40′ 37·39″ N., 84° 17′ 20″ W.

Arnold, Capt. W. E. — Johnson, Mr. B. — Arnold, Mrs. — Lee, Judge. — Barbour, Dr. — Murphy, Mrs. — Clarke, Mr. A. R. — Scott, Mr. — Cooper, Mr. W. G. — Searle, Mr. Arthur. — Crozer, Capt. W. C. — Wandelohr, Mr. C. A. — Grant, Mr. R. W. — West, Mr. — Hudnall, Judge. — Yelton, Mr. D. — Ireland, Mr. W. W.

Fisgard Island, 1860. — 47° 7½′ N., 122° 42″ W.

Parsons, Capt. — Richards, Capt.

Fiume (*Monte Calvario*), 1842. — 45° 20′ 6″ N., 14° 26′ 36″ E.

Mikocz, Prof. G. A.

Fleet Street (*London*), March, 1858.

Simms, jun., Mr. W.

Frauenberg, 1851. — 54° 22′ N., 19° 41′ E.

Brunnow, Dr. F. — Galle, Dr. J. G. — Feldt, Dr. L. — Wolfers, Dr.

Frederiksvoern, 1851. — 58° 59′ 33·9″ N., 10° 3′ 52″ E. — Sometimes called **Fredrichsvaarn.**

d'Abbadie, M. Antoine. — Hagerup, Lieut. — Adams, Prof. J. C. — Liveing, Prof. — Andrewes, Capt. — Riis, M. — Broch, M. — Stephenson, Mr. R.

Fuente del Mar, *near Santander, Spain.*

Almond, Mr. W. R. — Lowe, Mr. E. J. — Ellis, Mr. H. S. — Morley, Mr. S.

Fyldpaa, 1851. — 59° 20′ N., 10° 20′ E.

Jackson, Mr. Stephen. — King, Mr.

Gibraltar, 1870. — 36° 8′ N., 5° 20′ W.

Abbatt, Mr. R. — Smith, Mr. S. G. — Goodwin, Corporal. — Talmage, Mr. C. G. — Lethbridge, Capt. T. B. — Watkin, Lieut. H. — Parsons, Capt. — Wynne, Lieut. W. — Petley, Mr. W.

Gibraltar, (*near*) **Buena Vista,** 1870. — 36° 6′ 43″ N., 5° 20′ 51″ W. — [Prof. Newcomb.]

Newcomb, Prof. Simon. — Sprague, Mr. — Newcomb, Mrs.

Girgenti, 1870. — 37° 25′ N., 13° 35′ E.

Maucini, Prof. Francesco.

Goree (*W. Coast of Africa*), 1861. — 14° 40′ S., 17° 22′ W.

Dutailles, M. — Poulain, M.

Gorontalo, 1868. — 0° 29′ 41″ N., 123° 2′ 30″ E.

Riedel, M.

Göttenburg, 1851. — 57° 42′ 6·2″ N., 11° 57′ 45″ E. — Sometimes written **Göteborg.**

Petterssen, Lieut. C. A.

Göttenburg (*a Hill near*), 1851. — 57° 42′ 58″ N., 11° 56′ 20″ E. — [Swan.]

Swan, Mr. William.

Göttenburg (*Gotha Kellare Hotel*), 1851.

Aidie, Mr. John. — Chevallier, Rev. Temple.

Guardia, 1860. — 42° 34′ N., 2° 34′ W.

See **La Guardia.**

Gujfuli (*near Orduna*), 1860.

Pritchard, Rev. Prof. — Wright, Mr. John.

Guntoor, 1868. — 16° 17′ 29·23″ N., 80° 24′ 40″ E.

Branfill, Capt. — Tennant, Lieut.-Colonel J. F. — Phillips, Sergeant.

Guntoor (*near*), 1868.

Janssen, Dr. Jules.

Haddenham, March, 1858.

Dawes, The Rev. W. R.

Haddenham, 1860. — 52° 23′ N., 0° 10′ E.

Dawes, The Rev. W. R.

Hanover College (*Indiana*), 1869.

Allison, Mr. E. H. — Mulvey, Mr. O. — Archibald, Mr. G. D. — Thomson, Mr. J. H. — Bean, Mr. G. W. — Thomson, Mr. S. H. — Eastman, Mr. J. C. — Wiley, Mr. H. W. — Gill, Mr. Heber.

Hardingham (*Norfolk*), March, 1858.

Paroissien, The Rev. Challis.

Helsingborg, 1851. — 56° 4′ N., 12° 45′ E.

Blackwood, Capt. F. P. — Goodenough, Lieut.

Hereña (*Hill above*), 1860. — 42° 46′ 35″ N., 2° 53′ 12″ W.

Airy, Sir G. B. — Airy, Mr. W. — Airy, Lady. — Stead, Mr. — Airy, Miss.

Hestra (*Sweden*), 1851. — 57° 8′ N.

Bloomstrand, Herr Fr. Th.

Hingolee, 1847. — 19° 43′ 12″ N., 77° 7′ 5″ E.

Lysaght, Major.

Jaffna, 1871. — 9° 43′ N., 80° 10′ E.

Dawson, Mr. A. R. — Lewis, Mr. J. W. — Foenander, Mr. Francis. — Pargiter, Mr. — Fyers, Capt. A. B. — Temple, Mr. — Hall, Mr. — Tupman, Major G. L. — Hogg, Capt. J. R. — Vine, Mr. — Leembruggen, Mr. — Withers, Mr.

Jamkandi, 1868. — 16° 30′ 2″ N., 75° 20′ E. [Weiss.]

Campbell, Lieut. — Herschel, Lieut. John.

Jefferson City (*Iowa*), 1869. — 38° 36′ N., 92° 13′ W.

Ashe, Commander E. D. — Falconer, Mr. Alex. Pytt. — Douglas, Mr. — Vail, Mr. Hugh D.

Jerez de la Frontera, 1870. — 36° 43′ 56″ N., 6 10′ 8″ W. Also spelt **Xerez.**

Abbay, Rev. R. — Norman, Mr. — Clark, Mr. A. — Penrose, Mr. F. C. — Dean, Mr. G. W. — Pickering, Prof. E. C. — Ernst, Capt. — Pye, Mr. — Gannett, Mr. — Ross, Mr. — Gordon, Mr. J. C. — Willard, Mr. — Langley, Prof. S. P. — Winlock, Prof. J. — Naftel, Mr. P. J. — Young, Prof. C. A.

Jerez de la Frontera (*near*).

See **Maria Louisa Observatory.**

Iowa, 1869. — 40° 57′ N., 91° 38′ W.

Gould, Prof. B. A.

Iowa (*Mount Pleasant*), 1869. *See* **Mount Pleasant.**

Inch Bonney, *near Jedburgh*, 1836. — 55° 27′ 30″ N., 2° 33′ W.

Baily, Mr. Francis.

Ipswich, March 1858. — 52° 4′ N., 1° 8′ E.

Stuart, Mr. C.

Kaits, 1871. — 9° 43′ N., 80° 20′ E.

Dawson, Mr. A. R.

Kew Observatory, 1870.

Whipple, Mr. G. M.

Klipfontein. — 29° 14′ S., 17 40′ E.

Hall, Miss Alice. — Hall, Mr. Henry.

Kohklux, Alaska, 1869. — 59 23′ 41.6″ N., 135° 58′ 12″ W.

Davidson, Mr. George. — Throckmorton, Mr. — Seward, Governor Wm. H.

Konigsberg, 1851. — 54° 42′ N, 20° 31′ E.

d'Arrest, Dr. H. L. — Marth, Mr. A. — Busch, Dr. A. L. — Wichmann, Dr.

Kropp (*in Sweden*), 1851. — 56° 5′ 45″ N., 12° 49′ 38″ E.

Good, Mr. J. W.

La Guardia (*Hill of*), 1860. — 42° 34′ N., 2° 34′ W.

Atwood, Rev. H. S. — Gray, Rev. C. — Galton, Mr. F.

Lambessa, 1860. — 35° 29′ N., 6° 22′ E.

Bulard, M. C.

Lawoengan Island (*Pepper Bay, Java*), 1871.

Oudemans, Prof.

Laycock Abbey (*Wilts*),
March, 1858.

Smith, Mr. J. D.

Lilla Edet, 1851. — 58° 7′ N., 12° 8′ E.

Bond, Mr. G. P. — Mygind, Mr. S.
Carrington, Mr. R. C. — Svangren, Mr. L.

Lipezk, 1842. — 52° 36′ 43″ N., 37″ 35′ 30″ E.

Schidlowsky, M. — Struve, M. Otto.

Llodio (*Monte Arrana*), 1860. — 43° 7′ N., 2° 50′ W.

Murray, Mr. E. W. — Stronglein, Mr. John.
Rubenach, Mr. John.

Lodi, 1842. — 45° 19′ N., 9° 30′ E.

Piola, M.

Logrono (*Hill of Cantabria, near*),
1860.

Perry, Mr. J. G. — Pole, Prof. Wm.

Lomsa, 1851. — 53° 10′ N., 22° 15′ E.

Alexandrowicz, Herr. — Struve, M. Carl.
Döllen, Herr. W. — Struve, M. Otto.
Fuss, Herr Edward.

Manantoddy, 1871. — 11° 48′ N., 76° 4′ E.

Abbay, Rev. R. — Friswell, Mr.

Mangalore, 1871. — 12° 52′ N., 74° 54′ E.

Annappa, O. — Rosario, Mr. P. C.
Pillay, T. Gopalkristnah.

Mantawalu Kiki, (*Island in the Gulf of Gorontalo,*) 1868 — 0° 32′ 36″ S., 123° 4′ 48″ E.

Anson, Lieut. Chas. Vernon. — Oudemans, Dr.
Bullock, Capt. C. M. — Ricart, Padre Juan.
Clapp, Lieut. E. S. — Ross, Lieut. Andrew.
Fauro, Padre. — Ross, Mr. Thos. R. J.
Montealto, Dr. Geo. — Sutton, Mr. Fred. Wm.
Nouvell, Padre Santiago. — Tirffey, Mr. H.

Maria Louisa Observatory, (*Between San Lucar and Jerez,*) 1870. — 36° 38′ N., 6° 12′ W.

Lord Lindsay's party.

Becker, Mr. C. — Lasselatta, Señ. Aurelio.
Brogi, Señ. — Lindsay, Lord.
Browne, Lieut. Alex. B. — Pitman, Mr.
Campbell, Mr. Chas. — Reade, Mr.
Davis, Mr. H. — Rogers, Mr.
Gonzales, Señ. — Scott, Mr.
Greaves, R. N., Lieut. — Thuillier, Señ. Adolphus.
Hood, Mr. — Thuillier, Señ. Edward.
Iglesius, Don Jose. — Winson, Mr.

Marienburg, 1851. — 54° 2′ N., 19 2′ E.

Talbot, Mr. H. F.

Marseille, 1842. — 43° 16′ N., 5° 23′ E.

Valez, M.

Masulipatam, 1868. — 16° 11′ 33″ N., 81° 12′ 15″ E.

Pogson, Mr. N. R. — Walker, Mr. C. J.
Sharp, Rev. John. — Winter, Mr. G. K.

Mattoon (*Illinois*), 1869. — 39° 29′ 10·2″ N., 88° 23′ 7″ W.

Bostwick, Mr. C. B. — Marshall, Rev. C. H.
Easterday, Prof. L. M. F. — Murray, Prof. David.
Hill, President Thos. — Simons, Mr. Thos.
Hough, Prof. G. W. — Smith, Prof. F. H.
House, Mr. J. C. — Swift, Mr. Lewis.
Keifer, General J. W. — Twining, Prof.

Milan, 1842. — 45° 25′ N., 9° 10′ E.

de Bréra, M. — Kuhn, Lieut.
Carlini, Prof. — Magrini, Prof. Luigi.
Huyn, Capitaine Comte. — Majocchi, M.

Milan, 1860.

Burzetti, Sig. — Dembowski, Baron H.

Miranda de Ebro, (*Photographic station near,*) 1860.

See **Rivabellosa**, Mr. De la Rue's station.

Miranda de Ebro (*a Hill near*), 1860. — 42° 43′ N., 2° 59′ W.

Beck, Mr. Joseph. — Preston, Mr.
Beck, Mr. Walter. — Roberts, Mr. Joshua R.
Bonomi, Mr. J. — Weedon, Mr. F. M.

Montpellier, 1842. — 43° 35′ N., 3° 52′ E.

Delessert, M. B. — Petit, M.
Delile, M.

Mount Pleasant (*Iowa*), 1869. — 40° 47′ N., 91° 31′ W.

Carbutt, Mr. John. — Pickering, Prof. E. C.
Clifford, Mr. H. W. — Ranger, Mr. W. V.
Cremer, Mr. James. — Watson, Prof. J. C.
Leisenring, Mr. — Wilson, Mr. E. L.
Morton, Prof. Henry.

Mulwar, 1868. — 16° 34′ 40·0″ ± 1·6″ N., 75° 49′ 15″ E.

Engelmann, Dr. R. — Spörer, Prof.
Koppe, Herr C. — Tietjen, Dr. F.

Narbonne, 1842. — 43° 10′ N., 3° 0′ E.

Boisgiraud, M. — Pinaud, M.

New Albany (*Indiana*), 1869. — 38° 20′ N. 85° 50′ W.
Aycrigg, Col. Benj. — Reid, Mr.
Campbell, Prof. — Russell, Mr. L.
Crosier, Dr. — Smith, Mr. Geo. M.
Matthews, Mr. — Wilson, Mr.

Nice, 1861. — 43° 42′ N. 7° 18′ E.
Talmage, Mr. C. G.

Novarre, 1851. — 45° 27′ N. 8° 38′ W. — Also called **Novara.**
Bayma, Prof.

Oakland (*Kentucky*), 1869. — 37° 2′ 29·80″ N. 86° 15′ 18″ W.
de Brie, Mr. — Strange, Mr.
Langley, Prof. S. P. — Wilder, Mr. Graham.

Ocucaje (*near Pisco, Peru*), 1853. — 14° 21′ 21″ S. 22ᵐ 12·78ˢ E. of Santiago.
Lira, M. — Moesta, Don Carlos.

Ofen, 1842. — 47° 29′ 10″ N. 19° 3′ 3″ E.
Mayer, Dr.

Ogdensburg (*N. Y.*), 26 May, 1854. — 44° 31·3′ N. 75° 30′ 30″ W.
Alexander, Prof. Stephen. — Strong, Mr. R. M.
Gibson, Mr. W. J.

Olmos (*Peru*), *Station near*, 1853. — 6° 0′ 2″ S. 79° 42′ 53·4″ W.
Gilliss, Lieut. J. M.

Ootacamund, 1871. — 11° 24′ N. 76° 47′ E. — Also called **Ootakamund.**
Boesinger, Mr. J.

Oran, 1870. — 35° 34′ N. 0° 40′ W.
Carpenter, Mr. J.
Collins, Major.
Crookes, Mr. Wm.
Howlett, The Rev. F.
Huggins, Dr. William.
Noble, Capt. Wm.
Ommanney, Admiral Erasmus.
Ommanney, Lieut. Montague.

Oran (*near*), 1870.
Tyndall, Prof. J.

Orduña (*a Hill above*), 1860. — 42° 59′ N. 2° 58′ W.
Greenbank, Mr. Henry. — Reynolds, Mr. R.
Mathews, Mr. H. M. — Simon, Mr. F.
Pamler, Mr. Thos.

Oropesa (*Cape*), 1860. — 40° 7′ N. 0° 6′ E.
Capello, M. — Ribeiro, M.
Marquès, M. — Souza, Dr.

Osealousa, 1869.
Gummery, Prof. S. G. — McClune, Prof. James.

Ottumwa (*Iowa*), 1869. — 41° 2′ N. 93° 23′ W.
Alexander, Prof. — Himes, Prof. Chas. F.
Baker, Mr. W. J. — Moelling, Mr. E.
Browne, Mr. J. C. — Zentmayer, Mr. J.

Padua, 1842. — 45° 14′ N. 11° 56′ E.
Biela, Capt. — Pietropoli, Dr.
Conti, M. — Santini, M.

Pancerbo, 1860. — 42° 39′ N. 3° 5′ W.
Chevallier, The Rev. Temple. — Wilson, Mr. J. M.

Paramagira, 1858. — 25° 30′ 33·24″ S. 48° 26′ 58·59″ W.
d'Azambuja, M.
Baraúna, Capt. Brasalio da Silva.
Coelho, Lieut. J. Francisco.
Galvão, Capt. Rufino Eneas Gustavo.
Liais, Dr. Em.
de Mello, M. Antonio Mausel (Direct. de l'Observ.)
Numes, Capt. Francisco Duart.

Pavia, 1842. — 45° 16′ N. 9° 2′ E.
Baily, Mr. Francis.

Pena Cerrada, 1860. — 42° 38′ N. 2° 40′ W.
Grant, Prof. R. — McTaggart, Dr.
Jacob, Capt. W. S.

Pena de Castilla (*near Santander*), 1860.
Heath, Mr. R. F.

Perpignan, 1842. — 42° 41′ 43″ N. 2° 51′ 50″ E.
Arago, M. F. — Langier, M.
Fauvelle, M. — Mauvais, M. Victor.
Jaubert, M. — Mayette, M.

Pinheiros, 1858. — 25° 31′ S. 48° 26′ W.
Aranjo, M. F. G. — de Birto, Capt. C. R.

Pisco.—*See* **Ocucaje.**

Pobes, 1860. — 42° 48′ 2·3″ N. 2° 57′ 48·8″ W.
Struve, M. Otto.

Pobes (*Hill of Sta. Marina, near*), 1860. — 42° 47′ 12″ N. 2° 56′ 12″ W.
Weiler, Herr C. — Winnecke, Dr. A.

Poodoocotta, 1871. — 10° 25′ N. 79° 15′ E.
Holiday, Mr. H. — Respighi, Prof. L.

Puerto de Sta. Maria, 1870. — 36° 38′ N. 6° 10′ W.
Hammond, Mr. B. E.

Pulmotte, 1871. — 9° 12′ N. 80° 51′ E.
Ferguson, Mr. A. M. — Moseley, Mr. H. N.

Rœvelsberg, *near Engelholm,* 1851.
Dawes, Rev. W. R. — Hind, Mr. J. R.

Rastenburg, 1851. — 54° 4′ 55·7″ N. 21° 24′ E.
Billerbeck, Herr A. — Thiel, Herr.
Jaensch, Herr. — Thormann, Herr F.
Techow, Herr. — Schmidt, Dr. Julius.

Rawlins (*Wyoming Territory*), 1878.
Dr. Draper's Party.
Barber, Prof. — Edison, Mr.
Draper, Dr. H. — Lockyer, Mr. J. N.
Draper, Mrs. — Morton, Prof.

Ringeriget, 1851. — Not far from Christiania.
Krag, Lieutenant.

Rivabellosa, 1860. — 42° 43′ 24″ N. 2° 55′ 20″ W.
Beck, Mr. E. — De La Rue, Mr. Warren.
Beckley, Mr. — Downes, Mr.
Clark, Mr. S. — Reynolds, Mr.

Rixthöft, 1851. — 54° 49′ 53″ N. 18° 35′ 15″ E.
Busch, Dr. — Littrow, Dr. C. L. von.
Fearnley, Prof. C. — Scina, Prof. Ragond-.
Koch, Herr Hugo.

Salon, 1842. — 43° 38′ N. 5° 8′ E.
Attenoux, M. Auguste. — Largeteau, M.

Saint Louis (*Missouri*), 1869. — 38° 38′ 03·2″ N. 90° 12′ 14″ W.
Cobb, Mr. — Pitzman, Major J.
Eimbech, Prof. Wm. — Rodgers, Mr. W. H.
McMath, Mr. — Soldan, Mr.

Saint Louis (*Senegal*), 1861. — 16° 0′ N. 16° 32′ W.
French officers.

San Antonio, 1870. — 36° 37′ 14″ N. 6° 11′ 13″ W.
Browne, Mr. F. H. — Maclear, Commander.
Hostage, Mr. — Perry, Rev. S. J.
Hudson, Mr. W. H. H. — Toynbee, Captain H.
Ladd, Mr. W.

San Lorenzo (*Mountain near Ezcaray*), 1860. — 42° 20′ N. 3° 2′ W.
Foot, Mr. George. — James, Mr. G. H.
Gervey, Mr. G. E. — Winter, Mr. R.

San Lucar de Barrameda, 1870. — 36° 40′ N. 6° 23′ W.
Baynes, Mr. — Moulton, Mr. J. F.
Marquez, Senor Sanchez.

Santander (*near*), 1860. — 43° 26′ N. 3° 41′ W.
Hobbes, Mr. R. J. — Thompson, Commander.

Seyne, 1842. — 44° 21′ N. 6° 24′ E.
Savourin, M.

Shelbyville, 1869. — 38° 12′ 45·36″ N. 85° 13′ 22″ W.
Agnew, Mr. F. H. — Peirce, Prof. B.
Blake, jun., Mr. F. — Searle, Mr. G. M.
Bowditch, Mr. J. I. — Seymour, Prof. C. B.
Clark, Mr. Alvan G. — Stevens, Mr. Albert.
Clark, Mr. George D. — Tevis, Mr. R. C.
Dean, Mr. G. W. — Whipple, Mr. J. A.
Dixwell, Mr. J. J. — Williams, Mr.
Prendergast, Mr. John. — Winlock, Prof. Joseph.

Sholoor (*India*), 1871. — 11° 27·8′ N. 76° 42′ 45″ E.
Janssen, Dr. Jules.

Sidney, 1857. — 33° 51′ S. 151° 15′ E.
Clarke, Rev. W. B.

Sierra de Toloño (*Pena Cerrada*), 1860. — 42° 38′ N. 2° 40′ W.
Grant, Prof. R. — McTaggart, Dr.
Jacob, Capt. W. S.

Sioux County (*Iowa*), 1869. — 42° 34′ N. 96° 15′ W.
Abbe, Prof. Cleveland. — Gilman, Mr. W. S.

Springfield (*Illinois*), 1869. — 39° 49′ 02·50″ N. 89° 38′ 24″ W.
Aycrigg, Mr. Benjamin. — Meek, Mr. F. B.
Black, Mr. J. W. — Montague, Mr. W. P.
Carter, Mr. George T. — Peirce, Prof. C. S.
Dudley, Mr. Timothy. — Pourtales, Mr. L. F.
Fay, Mr. C. N. — Schott, Mr. Chas. A.
Fitzgerald, Mr. R. — Seaver, Mr. E. P.
Goodfellow, Mr. — Twining, Prof. A. C.
Jackman, Mr. — Warner, Prof. J. W.
McLeod, Mr. R. A.

Steilacoon, 1860. — 47° 2′ 54″ N. 122° 37′ 24″ W.
Casey, Lieut. Thos. L. — Gilliss, Lieut. J. M.

Storlus, — 53° 16′ 34·4″ N. 18° 30′ 30″ E.
Brohm, Herr. — Parpart, Prof. A. von.
Funh, Dr. — Schubart, Dr.

St. Paul Junction (*Plymouth Co., Iowa*), 1869. } 42° 47′ 30″ N. 96° 8′ 42″ W.

Ball, Mr. S. · Locklin, Mr. Eugene.
Farrell, Mr. N. E. · Phelps, Mr. L.
Farrell, Mrs. N. E. · Vincent, Mr. Leon.
Gilman, Mr. D. T. · Wood, Mr. Vincent.
Gilman, Mr. W. S., jun.

Syracuse, 1870. } 37° 3′ 53″ N. 15° 16′ E.

Brothers, Mr. A. · Griffith, Mr. C.
Eastman, Prof. J. R. · Hall, Prof. Asaph.
Fryer, Mr. A. · Harkness, Prof. Wm.
Gardner, Sapper Wm. · Tupman, Major G. L.

Tarazona, 1860. } 41° 59′ N. 1° 42′ W.

Auerbach, Herr. · Bruhns, Prof. C.

Terranova, 1870. } 37° 3′ 56·2″ N. 14° 14′ 15″ E.

Legnazzi, Prof. · Nobile, Prof. A.
Lorenzoni, Dr. E. · Serra, Capt.
Müller, Comr. Diamilla. · Tacchini, Prof.

Torre Blanca, 1860. } 40° 15′ 10″ N. 0° 10′ E. [Donati.]

Bonet, Prof. · Simonelli, Prof.
Carlini, Prof. · Tempel, Prof. Guglielmo.
Donati, Prof. G. B.

Toulon, 1842. } 43° 6′ N. 5° 58′ E.

Bérard, M. · Flaugergues, M.

Traheryd (*Sweden*), 1851. } 56° 35′ N. 13° 45′ E.

Galen, Dr. P. Van.

Trieste, 1842. } 45° 39′ N. 13° 46′ 30″ E.

Gallo, Prof.

Trincomalie (*near*), 1871.

Grubb, Capt. Alex.

Trollhättan Falls, 1851. } 58° 17′ 30″ N. 12° 23′ E.

Lassell, Mr. Wm. · Williams, Mr.
Stanistreet, Mr.

Tschernigow, 1842. } 51° 29′ 27·8″ N. 31° 15′ 43″ E.

Fedorow, Prof.

Tudela, 1860. } 42° 9′ N. 1° 38′ W.

Thompson, Rev. R. A.

Tune, *near Sarpsborg,* 1851. } 59° 14′ N. 11° 4′ 30″ E.

Gray, Mr. W.

Turin, 1842. } 43° 40′ N. 75° 26′ W.

Airy, Sir G. B. · Forbes, Prof.
Airy, Lady,

Tjebatjap (*Java*), 1871. } 7° 48′ S. 109° 5′ E.

Dietrich, Herr C.

Valencia, 1863. } 39° 30′ N. 0° 50′ W.

Haase, Kreigsrath C. · Rottenberg, Baron de.
Ibach, Herr. · Wallenberg, Dr. Carl von.
Redout, Lieut.

Vendôme, 1851. } 47° 49′ N. 1° 2′ E.

Renon, M. E.

Venice, 1842. } 45° 25′ N. 12° 19′ E.

Wissiak, Lieut. · Zantedeschi, M. l'abbé Francois.
Wullerstorff, M.

Vicenza, 1842. } 45 35′ N. 11 35′ E.

Casari, Prof. · Fusinieri, M.

Vienna, 1842. } 48° 12′ N. 16° 21′ E.

Bergius, Dr. · Littrow, Prof. J. J. von.
Elgg, Dr. O. W. von. · Schaub, Prof. F.
Hallaschka, Herr. · Schumacher, Prof. H. C.
Heider, Dr. M. · Stark, Herr.
Jüttner, Herr. · Steinheil, Prof.
Keserü, Herr. · Wallsee, Count Colloredo-.

Villasmunda, 1870. } 37° 13′ N. 15° 4′ E. } about.

Ranyard, Mr. A. C. · Samuelson, Mr. H.
Two sappers.

Visan (*near*), 1842.

Gerérin, M.

Vitoria, 1868. } 42° 50′ 41″ N. 2° 40′ 20″ W.

d'Achuria, Don Luis. · Mädler, Frau von.
d'Arrest, Prof. H. L. · Rennenkampff, Baron.
Barth, M. · Romers, M.
Bianchi, M. · Saar, M. Martin.
Cuillier, Herr. · Schulz, Herr G.
Echevenia, M. · Schulz, Herr, jun.
Goldschmidt, M. Hermann. · Thiele, M. Th. N.
Mädler, Prof. J. H. von. · Weyer, Prof.

Vunpurthy, } 16° 22′ 18″ N. 78° 3′ E.

Chary, C. Raganootha. · Rungacharry, C.
Lyengar, C. Appoo.

Wha Tonne, 1868. } 11° 42′ 35·0″ N. 99° 47′ 45″ E.

Béhic, M.
Bordes, Lieut.
Chabirand, M.
Garnault, M.
Hatt, M.
Hugon, M. le Baron Letourneur.
Olry, Lieut.
Pierre, M.
Rayet, M.
Stephan, Prof. E.
Tisserand, M.

White Top Mountain, *near Abingdon, Virginia,* 1869.

Myer, General Albert J.

Windsor (*New South Wales*), 1868. } 33° 34′ S. 150° 52′ E.

Tebbutt, Mr. J.

Yarrowlumla, Jan. 1851. } 39° 19′ S. 149° E.

Murray, Mr.

GENERAL INDEX.

A LIST OF PERSONS

TO WHOM

THE MEDALS OR TESTIMONIALS OF THE SOCIETY

HAVE BEEN ADJUDGED.

1823.

June 13. CHARLES BABBAGE, Esq.

The Gold Medal.—For his Invention of an Engine for computing and printing Mathematical Tables.

Professor JOHANN FRIEDRICH ENCKE.

The Gold Medal.—For his Investigations relative to the Comet which bears his name.

CHARLES RUMKER, Esq.

The Silver Medal.—For his Re-discovery of ENCKE'S Comet in 1822.

M. JEAN LOUIS PONS.

The Silver Medal.—For his Discovery of two Comets in 1822.

1826.

Feb. 7. J. F. W. HERSCHEL, Esq., and JAMES SOUTH, Esq.

The Gold Medal, each.—For their important Researches on the subject of Multiple Stars.

Feb. 10. Professor STRUVE.

The Gold Medal.—For his important Researches on the subject of Multiple Stars.

1827.

Feb. 2. FRANCIS BAILY, Esq.

The Gold Medal.—For his "New Tables for determining the places of 2881 Stars."

WILLIAM SAMUEL STRATFORD, Esq.

The Silver Medal.—For his Superintendence of the Computation of "New Tables for determining the places of 2881 Stars."

Feb. 5. Colonel MARK BEAUFOY.

The Silver Medal.—For his valuable Collection of Observations, particularly those of the Eclipses of *Jupiter's* Satellites.

1828.
Jan. 11. Sir THOMAS MACDOUGALL BRISBANE, K.C.B.
The Gold Medal.—For his Establishment of an Observatory, and for an important series of Observations made at Paramatta.

JAMES DUNLOP, Esq.
The Gold Medal.—For his Observations of the Nebulæ of the Southern Hemisphere.

Feb. 4. Miss CAROLINE HERSCHEL.
The Gold Medal.—For her recent Reduction to January 1800, of the Nebulæ discovered by Sir WILLIAM HERSCHEL.

1829.
Jan. 9. Rev. WILLIAM PEARSON.
The Gold Medal.—For his Work, entitled "An Introduction to Practical Astronomy."

Professor BESSEL.
The Gold Medal.—For his Zone Observations.

Professor SCHUMACHER.
The Gold Medal.—For the Publication of his various Astronomical Tables, and the "Astronomische Nachrichten."

1830.
Jan. 8. Mr. WILLIAM RICHARDSON.
The Gold Medal.—For his Investigation of the Constant of Aberration.

Professor ENCKE.
The Gold Medal.—For the New Berlin Ephemeris.

1831.
Jan. 14. Captain KATER.
The Gold Medal.—For his Invention of the Vertical Floating Collimator.

Baron DAMOISEAU.
The Gold Medal.—For his Memoir upon the Theory of the Moon, and for his Lunar Tables.

1833.
Jan. 11. Professor AIRY.
The Gold Medal.—For his Discovery of the long Inequality of *Venus* and the Earth.

1835.
Jan. 9. Lieutenant JOHNSON.
The Gold Medal.—For his Catalogue of 606 Southern Stars.

1836.
Jan. 8. Sir JOHN F. W. HERSCHEL.
The Gold Medal.—For his Catalogue of Nebulæ, printed in the "Philosophical Transactions" for 1833.

List of Persons to whom Medals or Testimonials have been adjudged.

1837.
Jan. 13. Professor ROSENBERGER.
The Gold Medal.—For his Investigations relative to HALLEY'S Comet.

1839.
Jan. 11. Hon. JOHN WROTTESLEY.
The Gold Medal.—For his Catalogue of the Right Ascensions of 1318 Stars.

1840.
Jan. 10. M. JEAN PLANA.
The Gold Medal.—For his Work, entitled "Théorie du Mouvement de la Lune."

1841.
Jan. 8. Professor BESSEL.
The Gold Medal.—For his Observations and Researches on the Parallax of 61 *Cygni.*

1842.
Jan. 14. M. HANSEN.
The Gold Medal.—For his Researches in Physical Astronomy.

1843.
Jan. 13. FRANCIS BAILY, Esq.
The Gold Medal.—For his Experiments to determine the Mean Density of the Earth in repetition of what is generally termed the "Cavendish Experiment."

1845.
Jan. 10. Captain WILLIAM HENRY SMYTH, R.N.
The Gold Medal.—For his "Bedford Catalogue," forming the second part of his work entitled "Celestial Cycle."

1846.
Jan. 9. GEORGE BIDDELL AIRY, Esq., Astronomer Royal.
The Gold Medal.—For his Reduction of the Observations of Planets made at the Royal Observatory, Greenwich, from 1750 to 1830.

1848.
Jan. 14. *Testimonials were awarded to*

GEORGE BIDDELL AIRY, Esq., Astronomer Royal.
For the Lunar Reductions recently made at Greenwich.

JOHN COUCH ADAMS, Esq.
For his Researches in the Problem of Inverse Perturbations leading to the Discovery of the Planet *Neptune.*

Professor ARGELANDER.
For his Catalogue of Stars.

GEORGE BISHOP, Esq.
For the Foundation of an Observatory leading to various Astronomical Discoveries.

List of Persons to whom Medals or Testimonials have been adjudged.

1848.

Jan. 14. Lieut.-Col. GEORGE EVEREST.
For his Measurement of the Indian Arc.

Sir JOHN F. W. HERSCHEL.
For his Work on the Southern Hemisphere.

Professor P. A. HANSEN.
For his Lunar Theory and Computation of Perturbations.

M. HENCKE.
For his Discovery of two Planets, *Astræa* and *Hebe.*

JOHN RUSSELL HIND, Esq.
For his Discovery of two Planets, *Iris* and *Flora.*

M. U. J. LE VERRIER.
For his Researches in the Problem of Inverse Perturbations leading to the Discovery of the Planet *Neptune.*

Sir JOHN LUBBOCK.
For his Researches in the Theory of Perturbations.

M. M. WEISSE.
For his Catalogue of Stars in BESSEL'S Zones.

1849.

Feb. 9. WILLIAM LASSELL, Esq.
The Gold Medal.—For the Construction of his Equatorial Instrument and for the Discoveries made with it.

1850.

Feb. 8. M. OTTO VON STRUVE.
The Gold Medal.—For his Paper on the Constant of Precession.

1851.

Feb. 15. Dr. ANNIBALE DE GASPARIS.
The Gold Medal.—For the Discovery of three Planets, *Hygeia, Parthenope,* and *Egeria.*

1852.

Feb. 13. Dr. C. A. F. PETERS.
The Gold Medal.—For his Papers on the Parallax of the Fixed Stars, and on the Constant of Nutation.

1853.

Feb. 11. JOHN RUSSELL HIND, Esq.
The Gold Medal.—For the Discovery of eight Planets, and other Astronomical Discoveries.

1854.

Feb. 10. M. CHARLES RUMKER.
The Gold Medal.—For his Catalogue of 12,000 Stars, and for other Astronomical Services.

List of Persons to whom Medals or Testimonials have been adjudged.

1855.
Feb. 9. Rev. W. R. DAWES.
The Gold Medal.—For his Astronomical Labours generally.

1856.
Feb. 8. ROBERT GRANT, Esq.
The Gold Medal.—For his "History of Physical Astronomy."

1857.
Feb. 13. M. SCHWABE.
The Gold Medal.—For his Discovery of the Periodicity of the Solar Spots.

1858.
Feb. 12. Rev. ROBERT MAIN.
The Gold Medal.—For his various Contributions to the *Memoirs* of the Society.

1859.
Feb. 11. R. C. CARRINGTON, Esq.
The Gold Medal.—For his "Redhill Catalogue of 3735 Circumpolar Stars."

1860.
Feb. 10. Professor P. A. HANSEN.
The Gold Medal.—For his Lunar Tables.

1861.
Feb. 8. M. HERMANN GOLDSCHMIDT.
The Gold Medal.—For his Discovery of thirteen of the Minor Planets, and other Astronomical Discoveries.

1862.
Feb. 14. WARREN DE LA RUE, Esq.
The Gold Medal.—For his Astronomical Researches, and especially for his Application of Photography.

1863.
Feb. 13. Professor ARGELANDER.
The Gold Medal.—For his Survey of the Northern Heavens.

1865.
Feb. 10. Professor G. P. BOND.
The Gold Medal.—For his work on the Comet of DONATI, and other Astronomical Researches.

1866.
Feb. 9. Professor J. C. ADAMS.
The Gold Medal.—For his Contributions to the Development of the Lunar Theory.

1867.
Feb. 8. W. HUGGINS, Esq., and Professor MILLER.
The Gold Medal.—For their Researches in Astronomical Physics.

1868.
Feb. 14. M. U. J. LE VERRIER.
The Gold Medal.—For his Planetary Tables.

List of Persons to whom Medals or Testimonials have been adjudged.

1869.
Feb. 12. E. J. STONE, Esq.
The Gold Medal.—For his Re-discussion of the Transit of *Venus* in 1769, and his other contributions to Astronomy.

1870.
Feb. 11. M. CH. DELAUNAY.
The Gold Medal.—For his "Théorie de la Lune."

1872.
Feb. 9. Signor G. V. SCHIAPARELLI.
The Gold Medal.—For his Researches on the Connexion between the Orbits of Comets and Meteors.

1874.
Feb. 13. Professor SIMON NEWCOMB.
The Gold Medal.—For his Tables of *Neptune* and *Uranus*, and other contributions to Mathematical Astronomy.

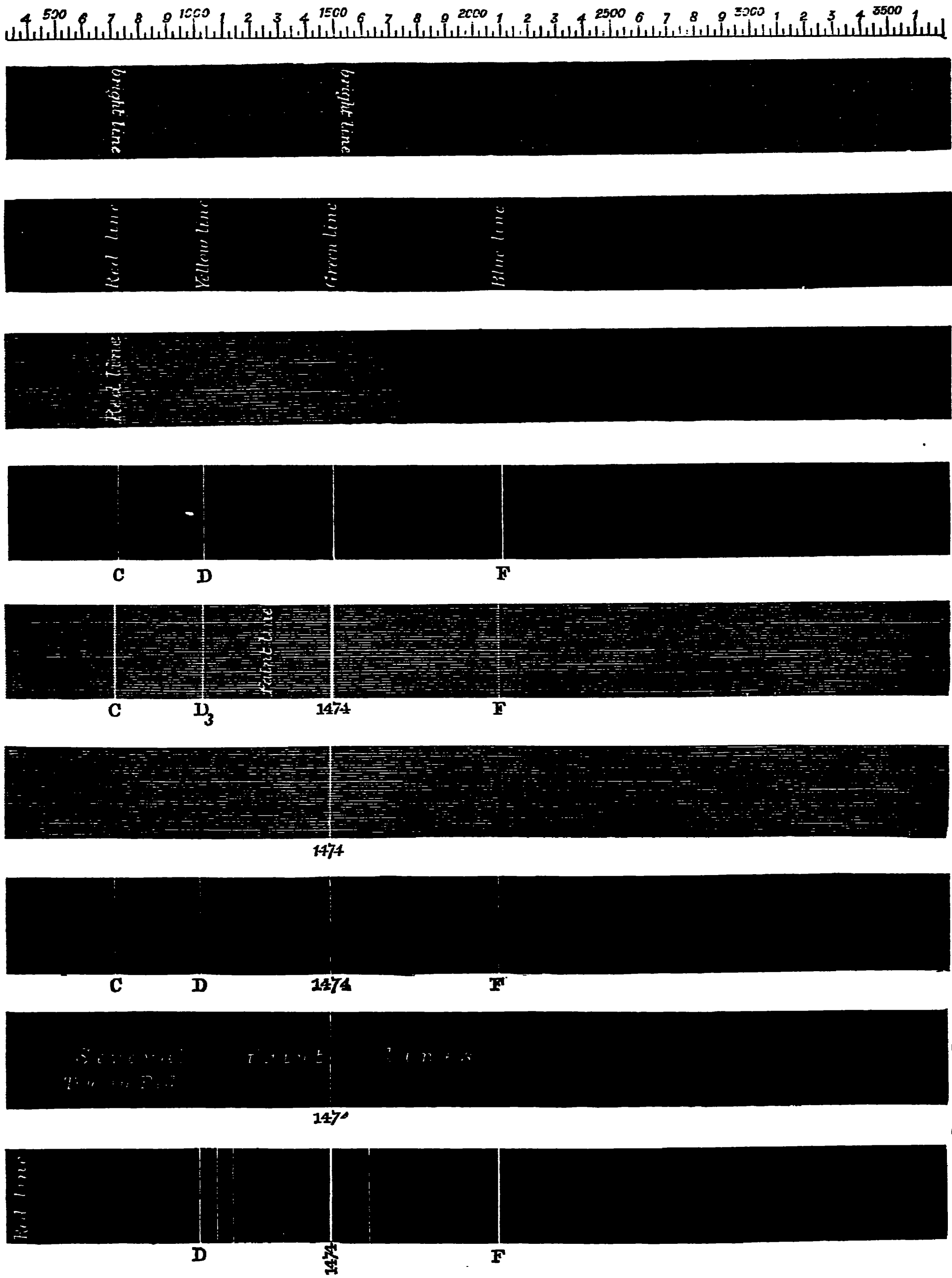
1875.
Feb. 12. Professor H. L. D'ARREST.
The Gold Medal.—For his Work entitled "Siderum Nebulosorum Observationes Havnienses, institutæ in Specula Universitatis per tubum sedecimpedalem Merzianum, ab anno 1861 ad annum 1867," and other Astronomical Works.

1876.
Feb. 11. M. U. J. LE VERRIER.
The Gold Medal.—For his Investigations of the Theories of *Jupiter*, *Saturn*, *Uranus*, and *Neptune*, and for his Tables of *Jupiter* and *Saturn*.

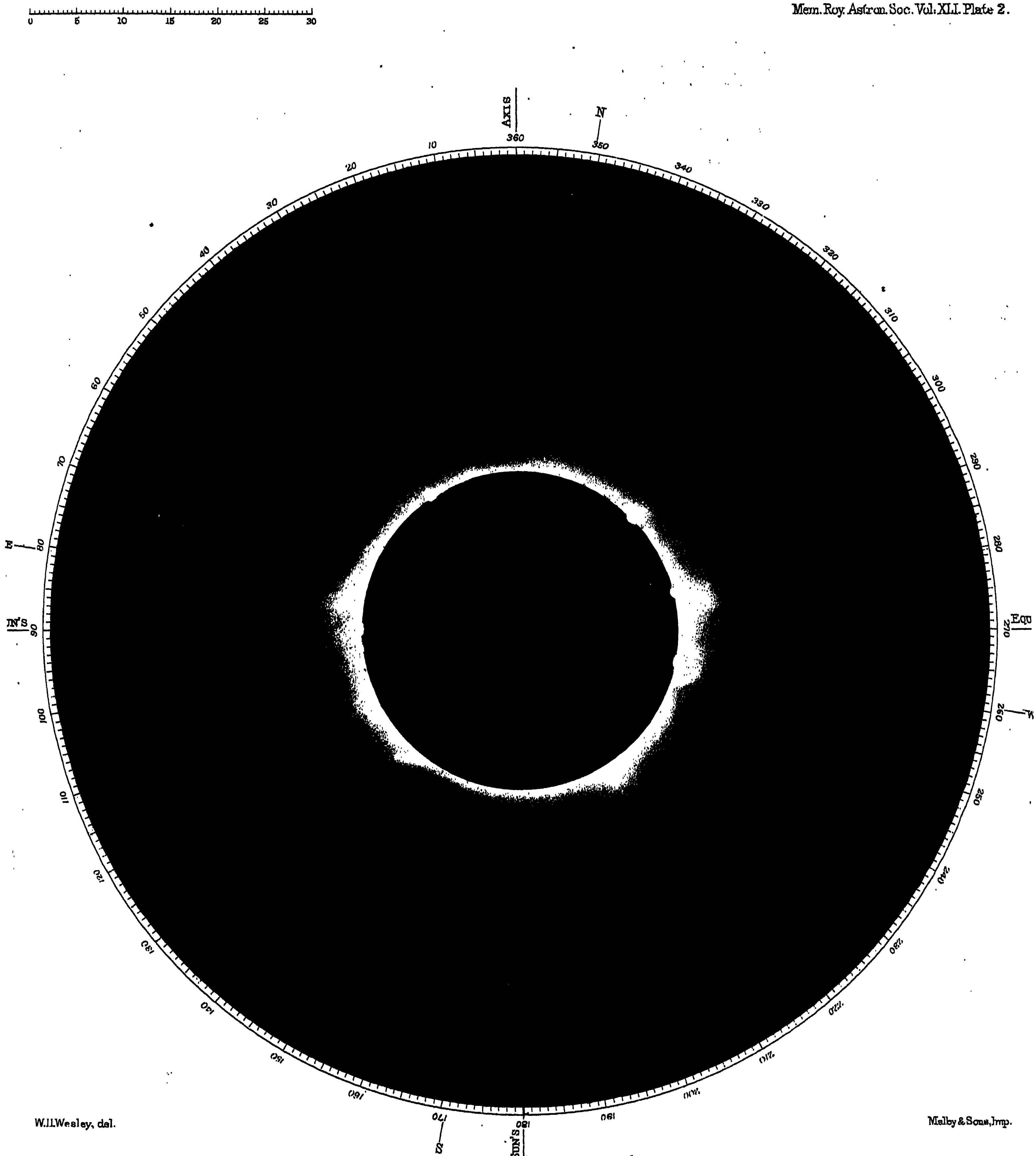
1878.
Feb. 8. Baron H. VON DEMBOWSKI.
The Gold Medal.—For his Researches on Double Stars.

1879.
Feb. 14. Professor ASAPH HALL.
The Gold Medal.—For his Discovery and Observations of the Satellites of *Mars*, and for his Determination of their Orbits.

SPECTRA OBSERVED WITH INTEGRATING SPECTROSCOPES.



Pickering, 1869.	(pp 406-7.) Continuous spectrum sufficiently bright to have its upper and lower edges well defined. No dark lines were seen, but two or three bright lines were observed : the brightest in the neighbourhood of E, the next near C.
Lawrence Smith, 1869.	(p. 414.) Four bright lines were seen : "one in the red, in or near the line C; one in the orange, in or near D ; one in the green ; and one in the blue, in or near F."
Hammond, 1870.	(pp. 424-5.) A spectrum was observed in which the red and green were present, but the blue and violet were absent, and upon the red was a line of brighter red. Hammond adds: "One fact of which I am quite sure is, that the red line was visible, and that the green coronal line was not."
Abbay, 1870.	(pp. 425-7.) For eight or ten seconds after the commencement of totality, the C, D, and F lines were extremely bright. C and D then disappeared, leaving F and another line (rather brighter than F), which was found to be between 1464 and 1494. No continuous spectrum was seen. The observation was made through passing clouds.
Pye, 1870.	(pp. 428-30.) For about one-eighth of a second at the commencement of totality, a great number of bright lines were seen, "the effect being as if all the dark lines of the spectrum were converted into bright ones." Then, with a wide slit, C, D, or probably D_3, 1474, and F were seen ; and just before the end of totality, a faint line, less refrangible than 1474, was seen for an instant. The estimated relative brightness of the lines was—C, 8·5 ; D_3, 5·5 ; 1474, 10 ; F, 3.
Saxton, 1871.	(pp. 459-60.) The bright lines C, D, and F seen at the beginning of totality. These faded, and 1474 made its appearance. "It remained for a short time only," and then, just before the end of totality, C, D, and F were seen again for a moment. Before totality, the cross-wires had been carefully placed in the position due to K 1474 ; during totality they appeared to intersect the bright line truly.
Fyers, 1871.	(pp. 465-7.) As totality commenced, the dark lines suddenly changed to intense brilliancy, resembling bright, sparkling threads. Their brightness only lasted one and a-half or two seconds, when they disappeared suddenly, leaving only four bright lines in the dark spectrum. The positions of these lines were pricked off three times by means of a recording spectroscope. The places of the lines pricked off agree nearly with C, D, 1474, and F No lines beyond F could be detected.
Tupman, 1871.	(p. 467.) The spectrum was only examined for a few seconds. 1474 was seen, together with several other extremely faint lines between C and F.
Ferguson, 1871.	(pp. 468-9.) For a few seconds after totality commenced all was dark ; then F suddenly appeared very bright, and continued of the same intensity till totality was over. About five seconds later three more lines made their appearance. These were judged to be 1474, D, or a line near D, and a dark-red line, estimated as *a*. About the middle of totality, a line slightly more refrangible than 1474 was observed rapidly appearing and disappearing. Just before the end of totality, three green lines flashed in between D and 1474. No continuous spectrum was seen.

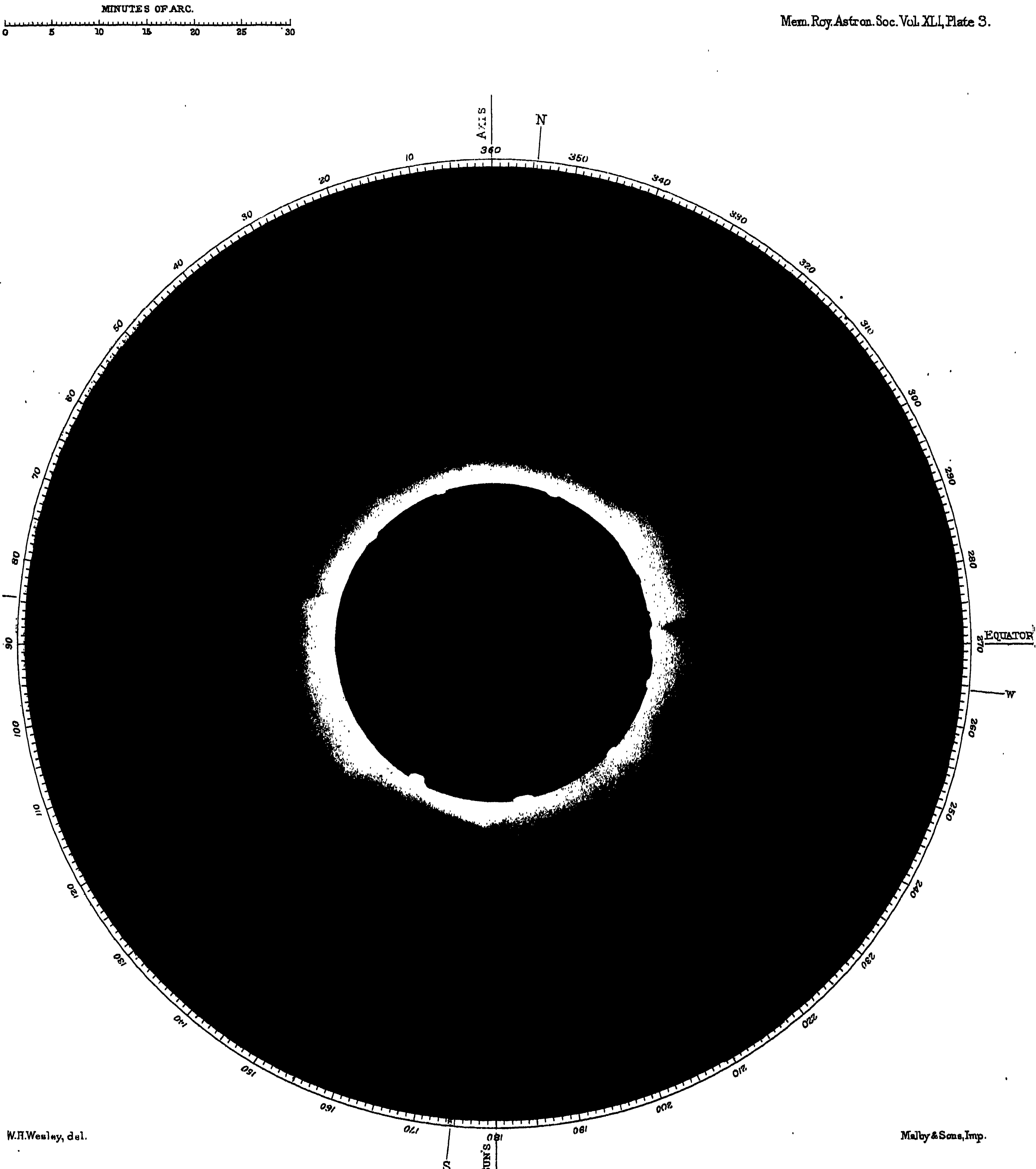


W. H. Wesley, del.

Malby & Sons, Imp.

TOTAL ECLIPSE OF THE SUN 28th JULY 1851.

Daguerreotype taken by Dr. Busch with the Konigsberg Heliometer.
The above drawing has been made from a steel engraving of the daguerreotype given in the 26th volume of the Konigsberg Astronomische Beobachtungen.

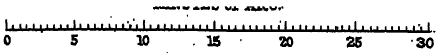


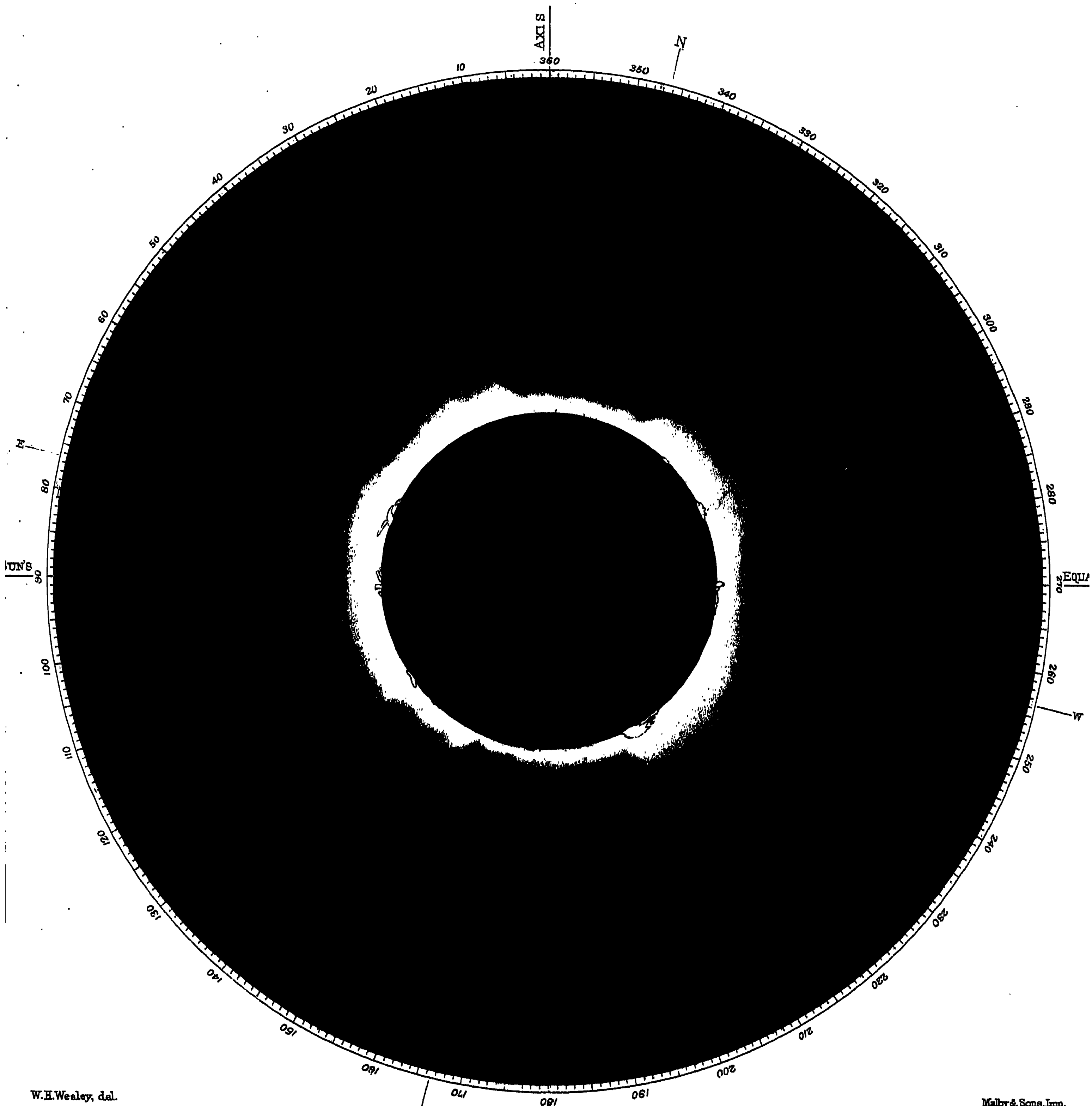
W. H. Wesley, del.

Malby & Sons, Imp.

TOTAL ECLIPSE OF THE SUN 18th JULY 1860.

The above drawing has been made by combining the details visible in photographic copies (on paper) of four negatives obtained at Desierto de las Palmas by M. Montserrat, with the telescope of Padre A. Secchi.





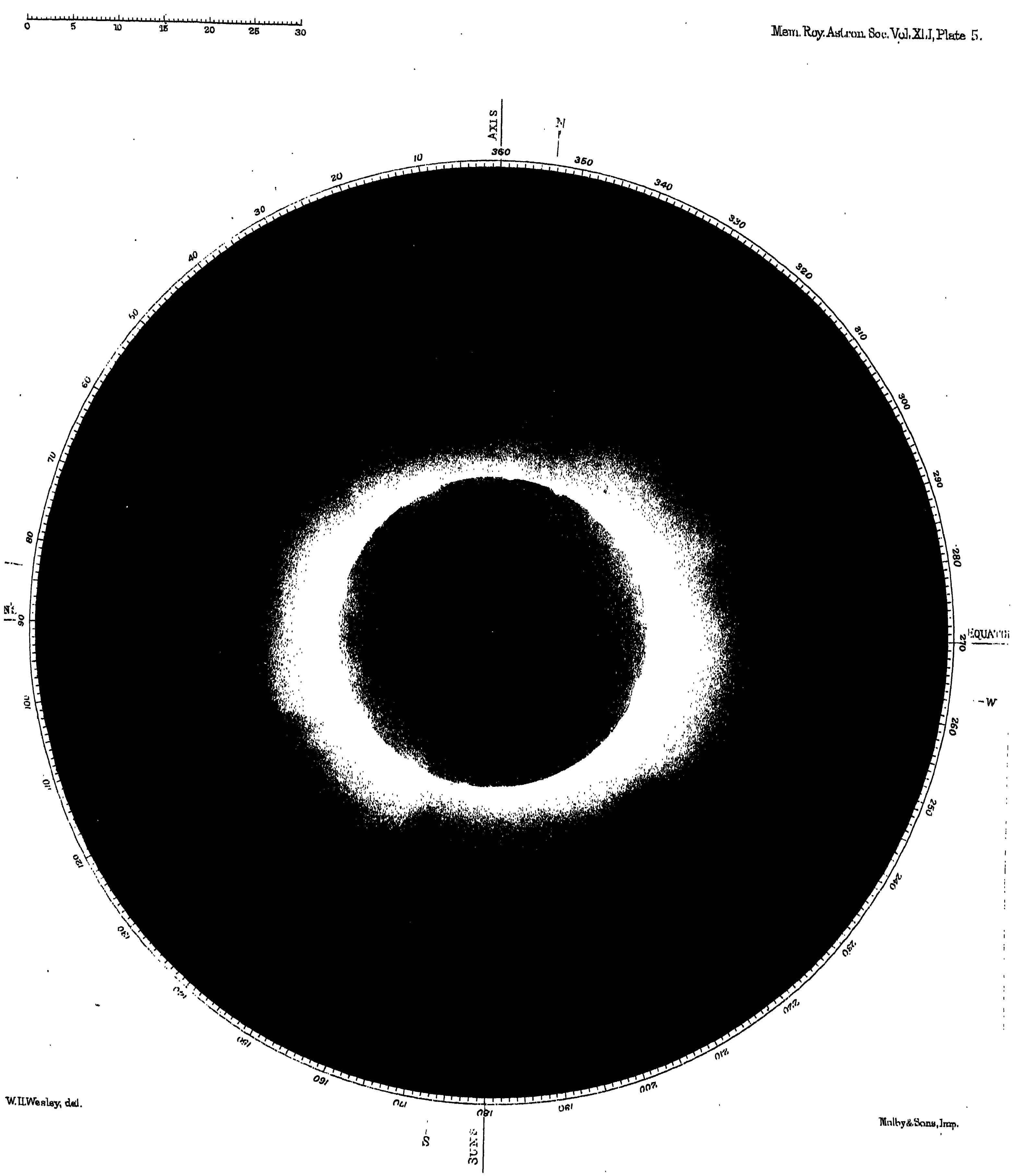
W.H.Wesley, del.

Malby & Sons, Imp.

TOTAL ECLIPSE OF THE SUN 7th AUG. 1869.

The above drawing has been made from photographic copies of a Negative obtained at Shellyville, Kentucky by Mr. J. A. Whipple.

(The forms of the prominences from which the orientation of the corona has been obtained have been taken from the Ottumwa photographs.).



W. H. Wesley, del.

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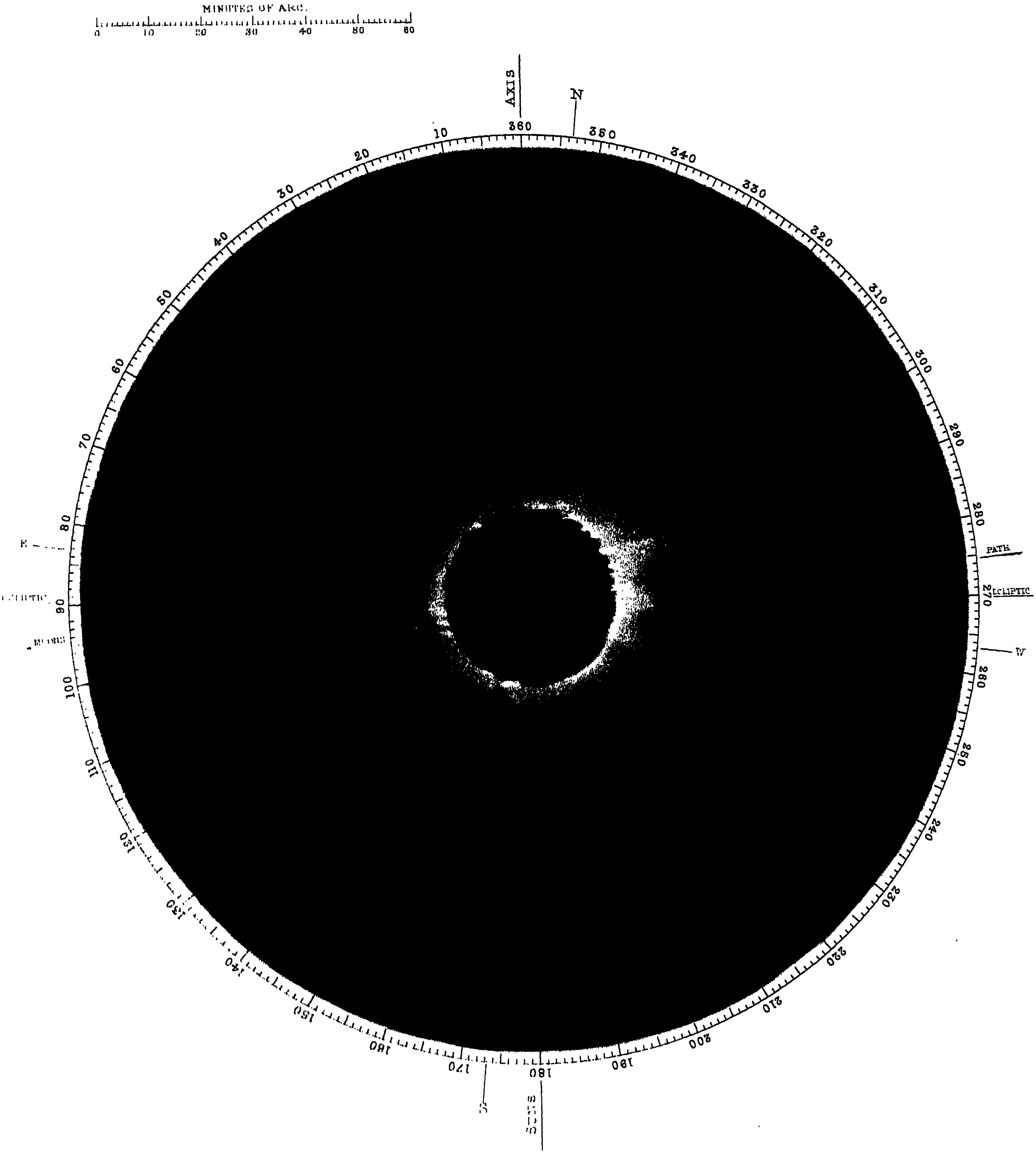
TOTAL ECLIPSE OF THE SUN 22nd DECr 1870.

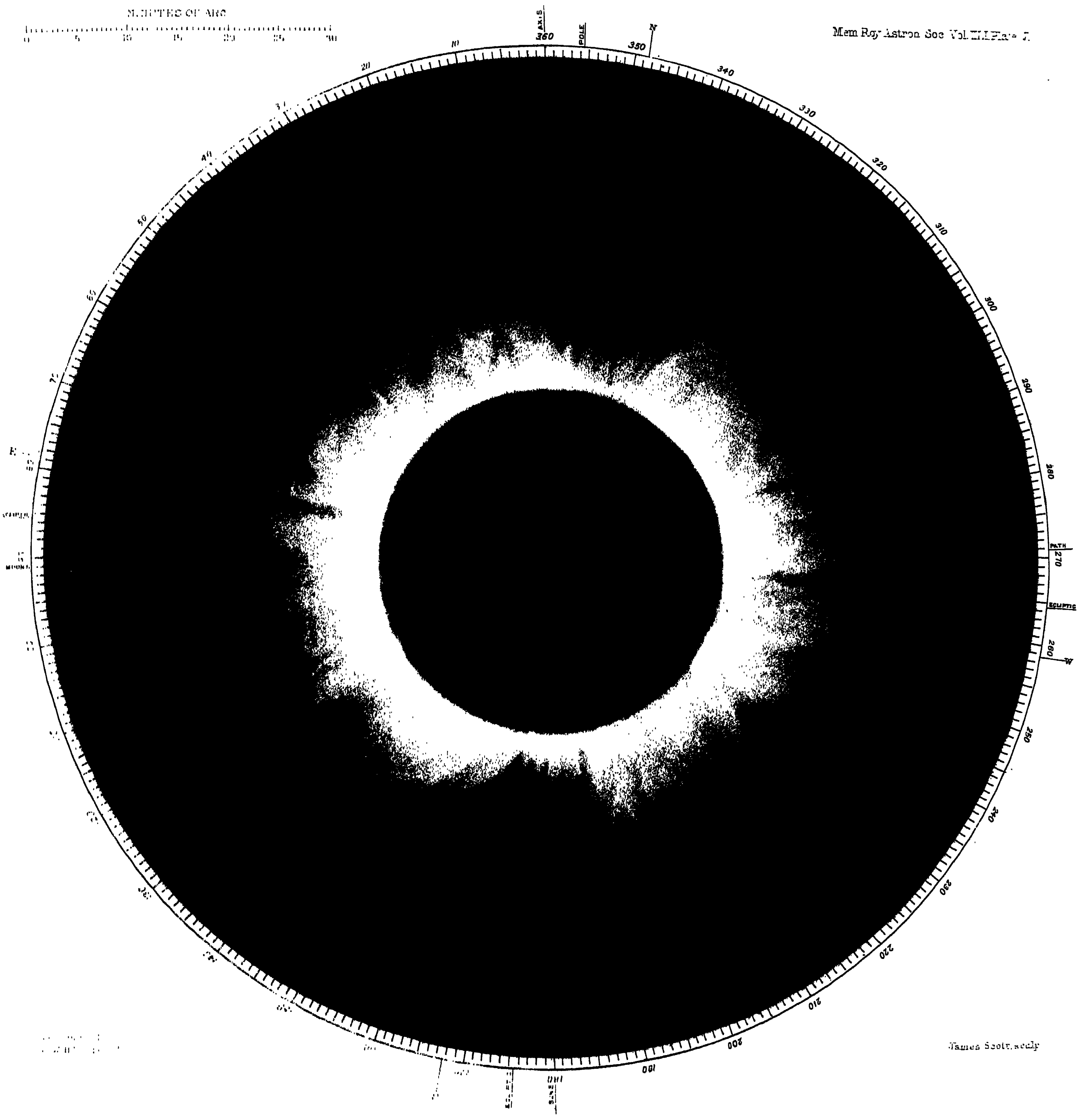
The above drawing has been made from a glass positive taken directly from the negative obtained at Jerez by Mr Willard.



TOTAL ECLIPSE OF THE SUN DEC^{R} 22, 1870.

ENGRAVED FROM A DRAWING MADE FROM THE ORIGINAL NEGATIVE TAKEN AT SYRACUSE

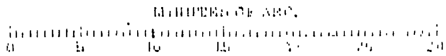
BY M^{R} BROTHERS.

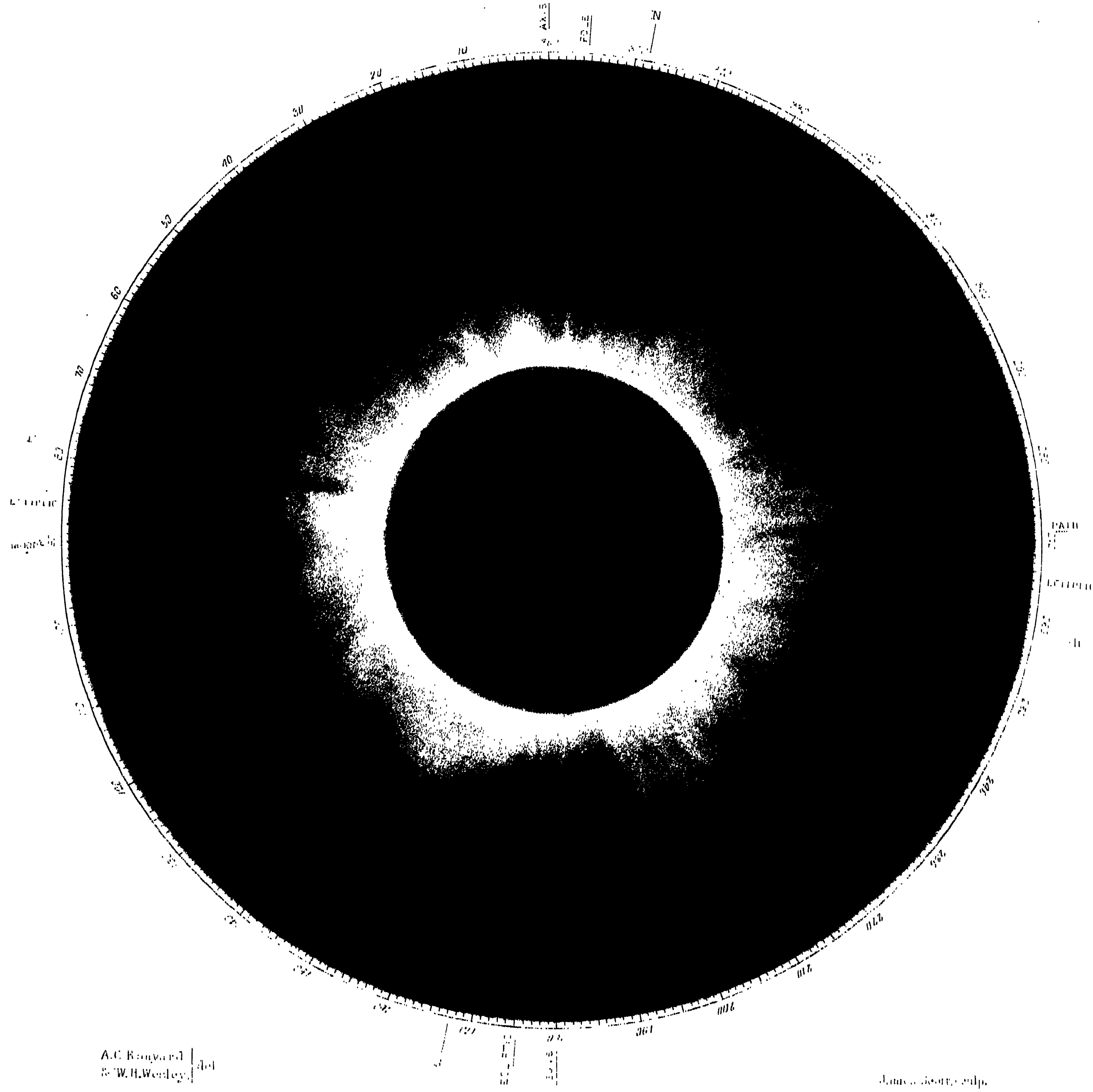


[illegible] OF THE SUN DEC^R 12. 1871.

[illegible] TAKEN AT BAIKUL.

[illegible] (M^R DAVIS)





A. C. Ranyard & W. H. Wesley del.

James Basire sculp.

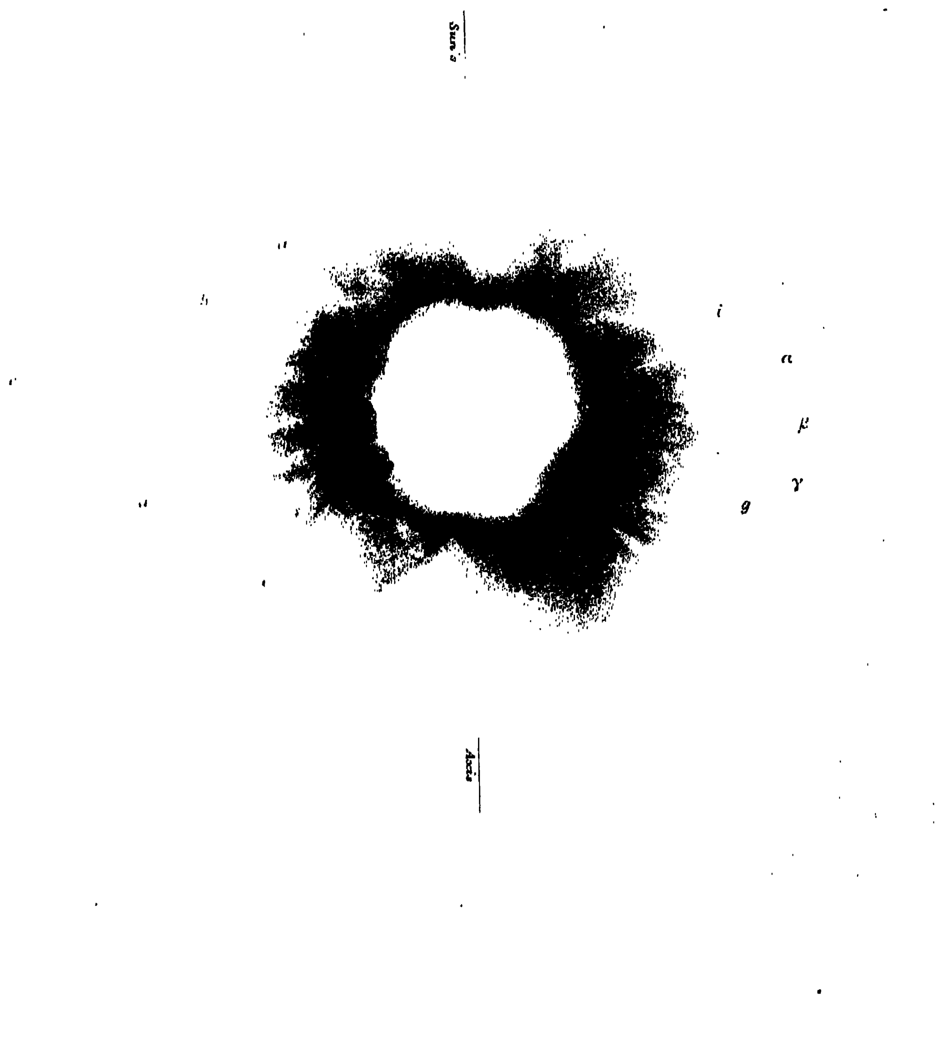
TOTAL ECLIPSE OF THE SUN DECEMBER 12, 1871.

ENGRAVED FROM A DRAWING MADE FROM THE ORIGINAL NEGATIVE TAKEN AT DODABETTA.

BY MR J. B. N. HENNESSEY AND CAPTAIN WATERHOUSE.

UNDER THE SUPERINTENDENCE OF COL. TENNANT.

DRAWING SHOWING THE PHOTOGRAPHIC DETAILS
OF NEGATIVE Nº 1. OF THE **DODABETTA** SERIES
Taken 12th Dec. 1871.
(Black representing white)



Line parallel to the edge of the Plate

Malby & Sons, imp.

W. H. Wesley, del.

Group A.

Malby & Sons, Imp.

GROUP OF CORONAL STRUCTURE VISIBLE IN THE PHOTOGRAPHS OF THE ECLIPSE OF

12TH DEC. 1871.

(black representing Opacity in the Negatives.)

W.H.Wesley, del. Group C. Malby & Sons, Imp.

GROUP OF CORONAL STRUCTURE VISIBLE IN THE PHOTOGRAPHS OF THE ECLIPSE OF

12TH DEC. 1871.

(black representing Opacity in the Negatives.)

NO DETAIL IS GIVEN IN THIS PLATE WHICH CANNOT BE MADE OUT IN AT LEAST THREE OF THE NEGATIVES

Group D.

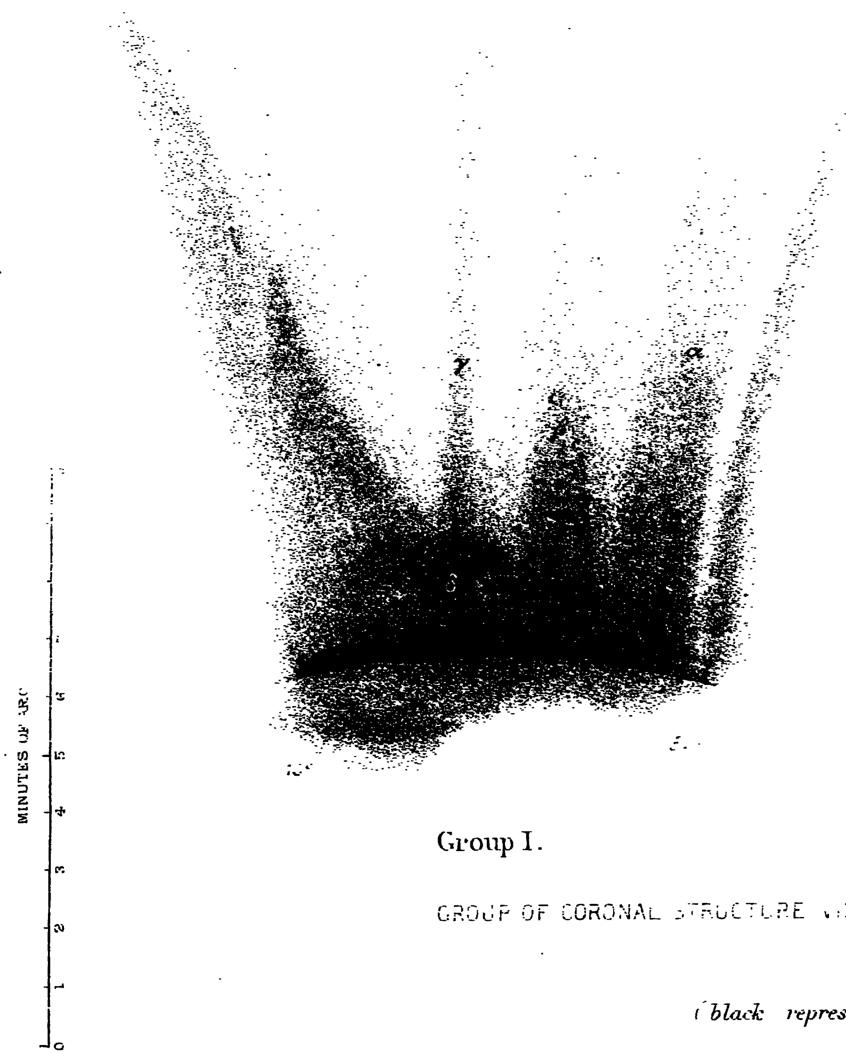
W.H.Wesley, del.

Mallby & Sons, Imp.

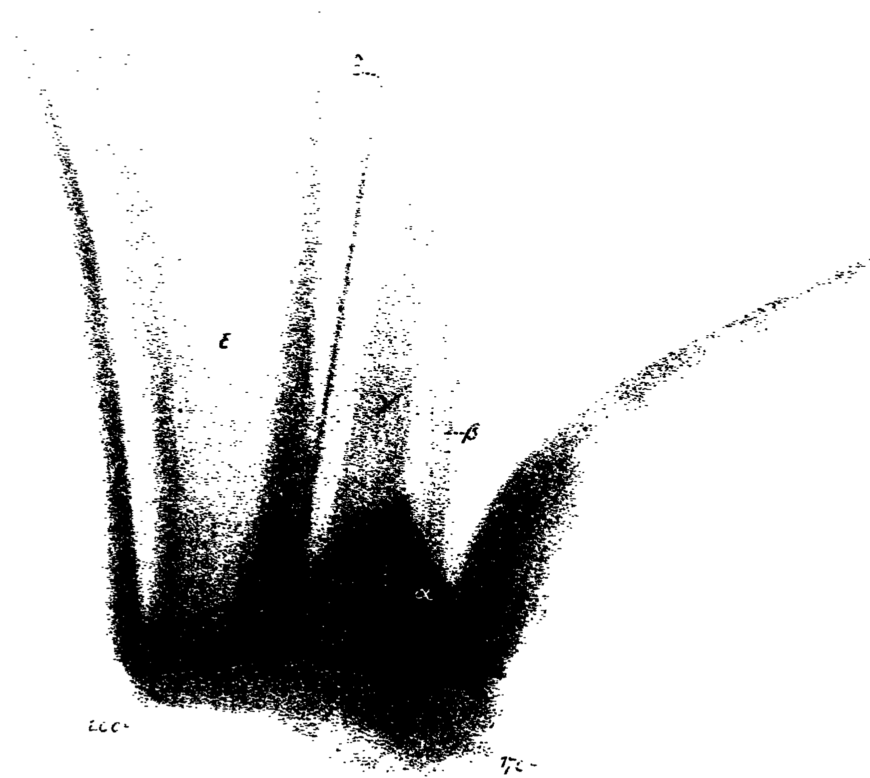
GROUP OF CORONAL STRUCTURE VISIBLE IN THE PHOTOGRAPHS OF THE ECLIPSE OF

12TH DEC. 1871.

(black representing Opacity in the Negatives)



Group I.



Group E.

GROUP OF CORONAL STRUCTURE VISIBLE IN THE PHOTOGRAPHS OF THE ECLIPSE OF

12TH DEC. 1871.

(black representing Opacity in the Negatives.)

NO DETAIL IS GIVEN IN THIS PLATE WHICH CANNOT BE MADE OUT IN AT LEAST THREE OF THE NEGATIVES

W.H.Wesley, del.

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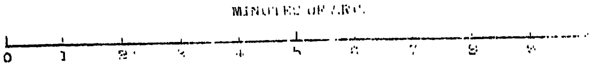

W.H.Wesley, del.

Group F.

Maltby & Sons, lith.

GROUP OF CORONAL STRUCTURE VISIBLE IN THE PHOTOGRAPHS OF THE ECLIPSE OF

12th DEC. 1871.

(black representing Opacity in the Negatives.)

NO DETAIL IS GIVEN IN THIS PLATE WHICH CANNOT BE MADE OUT IN AT LEAST THREE OF THE NEGATIVES.

MINUTES OF ARC.

Group G.

GROUP OF CORONAL STRUCTURE VISIBLE IN THE PHOTOGRAPHS OF THE ECLIPSE OF

12TH DEC. 1871.

(black representing Opacity in the Negatives.)

NO DETAIL IS GIVEN IN THIS PLATE WHICH CANNOT BE MADE OUT IN AT LEAST THREE OF THE NEGATIVES.

W.H.Wesley, del.

Malby & Sons

W.H.Wesley, del. 340° Group II. 290° Malby & Sons, Imp.

GROUP OF CORONAL STRUCTURE VISIBLE IN THE PHOTOGRAPHS OF THE ECLIPSE OF

12TH DEC. 1871.

(black representing Opacity in the Negatives.)

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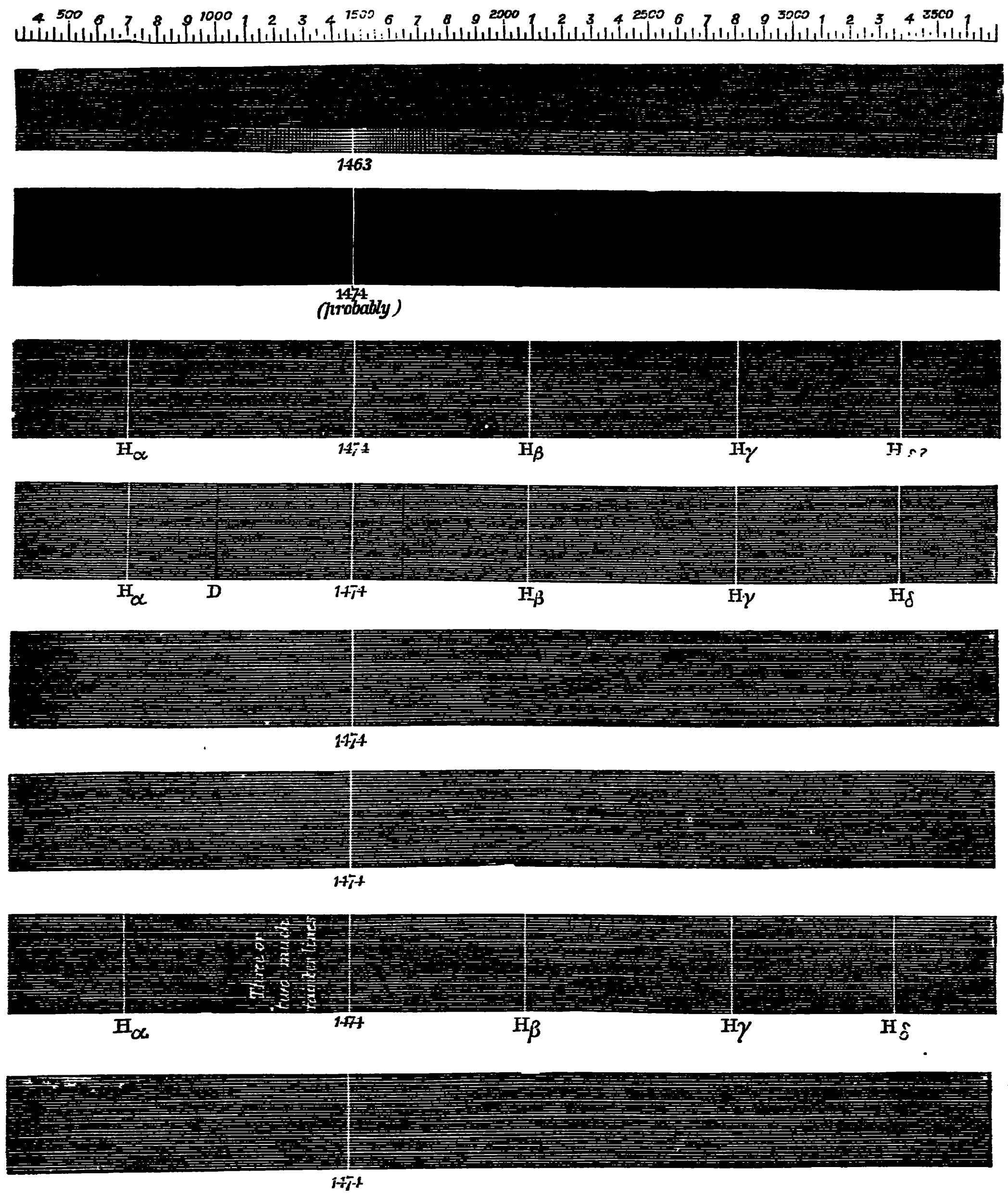
SPECTROSCOPES.



Riha, 1868. (pp. 382-4.) No information is given as to the position of the slit with regard to the image of the corona thrown upon the slit-plate. The bright-line spectrum seen towards the end of totality proves that the instrument was in adjustment.

Nobile, 1870. (p. 445.) Position of the slit upon the corona not mentioned. Nobile says that although the optical conditions of his instrument were good, he was unable to see any other bright line in the spectrum of the corona besides 1474.

Lockyer, 1871. (pp. 446-7.) Slit at a height of about 7′ from the western limb. (It would also seem that the slit must have been placed in other positions upon the corona.) The spectrum is described as "a vivid hydrogen spectrum with 1474 slightly extended beyond it."

Janssen, 1871. (pp. 450-54.) At a height of two-thirds of a radius above the limb, the lines of the hydrogen spectrum and the bright line 1474 were seen. As the slit was brought up towards the limb, the spectrum increased in brightness. At a height of from 5′ to 6′ above the limb, the dark line D and some dark lines in the green were observed.

Herschel and Tennant, 1871. (pp. 454-9.) Slit placed across the eastern edge of the southern rift. The bright line 1474 and a continuous spectrum was observed. At 8′ from the western limb, 1474 and faint continuous spectrum observed. At 16′ from the western limb no bright lines were visible, though a faint light was seen.

Moseley, 1871. (pp. 469-72.) Close to the moon's eastern limb, at the beginning of totality, C, D_3, 1474, F, and two faint green lines between D_3 and 1474, were seen. The slit was then carried to the moon's centre, but no spectrum could be detected. At a distance of 20′ or more from the moon's eastern limb, where the corona was plainly visible in the finder, no spectrum could be seen. The slit was then moved to a part of the corona estimated to be 22′ from the eastern limb, and the bright line 1474 was observed.

Stone, 1874. (Inner corona.) (pp. 473-5.) As the slit was swept across the inner corona, the hydrogen lines were seen extending across the field. There was also a line somewhere in the green, which proved to be 1474, and two or more much fainter lines of less refrangibility than the green line. These were seen upon a "pretty bright spectrum, which appeared continuous."

Stone, 1874. (Outer corona.) (pp. 473-5.) When the slit was directed to the outer corona only, one bright line, which was found to correspond with 1474, was observed. But besides the one bright line there were certainly dark or absorption lines present in the spectrum, though they were seen with great difficulty. The dark lines are not given in the woodcut, as their places were not determined.

MEMOIRS

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLII., 1873–1875.

WITH TWO PLATES.

LONDON:
PUBLISHED BY THE SOCIETY,
AT THEIR APARTMENTS,
BURLINGTON HOUSE.

1875.

PAPERS.

I. *Report on Observations of the Total Eclipse of the Sun on December 11-12, 1871, made, by order of the Government of India, at Dodabetta, near Ootacamund.* By Lieut.-Colonel J. F. Tennant, R.E., F.R.S.

The expedition of which I am now called on to give an account arose out of an enquiry whether, in the event of my being able to get leave of absence from my duties, Government would enable me to visit the central line of the Eclipse, in order to examine for myself some points on which doubts seemed to me to exist. At the time I made this enquiry, and for some time after, I had only the most meagre information as to the knowledge acquired in 1870, and my object then was mainly to seek out the sources of the contradictions which the American Eclipse of 1869 had produced, and to reconcile these, if possible. I had little time to procure instruments, and I was under the disadvantage of being far from all places where they could be got. I had, therefore, contemplated no extensive preparations, and was quite unprepared for an offer to supply funds for a regular expedition.

While enquiring as to the extent to which I might reckon on funds, I commenced negotiations for assistance, and hurriedly addressed both the Astronomer Royal and Dr. Huggins on the subject of instruments. In the end of May I was informed that a sum would be placed at my disposal (subject to the submission of a project and estimate of cost), which removed all anxiety except as to time. I therefore again addressed Dr. Huggins, hoping that I should be in a position to telegraph instructions for commencing work by the time my letter reached England. On the 7th June I submitted a proposal, of which a copy is annexed (Appendix A), but circumstances rendered a final decision on it later than I had hoped, and it was only in the middle of July that I was in a position to telegraph orders for work to be

commenced. Dr. HUGGINS had, however, taken action, as far as was possible, on my letters, and been in consultation with Mr. SIMMS as to the manner of supplying my wants so far as they could not be met by loans. I am, therefore, greatly indebted to Dr. HUGGINS; and also to the ASTRONOMER ROYAL, for the loan of one of the telescopes prepared for the *Venus* Transit; and to the Royal Astronomical Society for the loan of a spectroscope, and other small apparatus.

Major MONTGOMERIE, R.E., officiating as Superintendent of the Great Trigonometrical Survey, consented to lend the services of Mr. J. B. N. HENNESSEY and Captain HERSCHEL of his department, who I had ascertained were willing to share in my scheme; and I have to thank Colonel THUILLIER, Surveyor-General, for placing at my disposal Captain J. WATERHOUSE, Superintendent of the Photographic branch of his office.

Captain HERSCHEL was in November on leave at the Nilgherries. Mr. HENNESSEY left the head-quarters of the G. T. Survey at Dehra on November 17 for Bombay, where I expected that he would have had merely to pick up and bring on the instruments which had been sent out from England. Captain WATERHOUSE and I left Calcutta on November 21. We landed at Madras on November 25, and that day and the next were spent in arranging for our own transport and that of our apparatus to the Nilgherries. I had understood that Mr. HENNESSEY had passed on, but on our arriving at the point where the Madras Railway branches separate to the north and west respectively, we found Mr. HENNESSEY and his instruments, and from that point we proceeded together as far as the rail took us. The task of bringing down the instruments had been far from being as simple as I had hoped: arriving at Bombay, Mr. HENNESSEY found that the "Ispahan" carrying the cases was only just in, and in part discharged, and he had himself to seek for them in the hold so as to save time; there he found all but one, which it turned out had been landed, and which was only recovered by a search in various stores to which goods had been consigned. When we reached Coimbatoor Station, where railway carriage ceased, we found that the heavy and recent rains had injured a bridge close to the station, that traffic across it was stopped, and that there would be great difficulty with heavy cases: one, which was by far the most weighty, we therefore broke open, and divided the stand of Mr. AIRY's telescope which it contained, making thus three manageable portions. Captain WATERHOUSE and I then went on to Ootacamund, leaving Mr. HENNESSEY to follow with the heavy instruments: we reached our destination on November 28th, and at once commenced arrangements for our stay. Messrs. HENNESSEY

and HERSCHEL joined us on the 30th: and the next day we took possession of a house which I had hired as a depôt and head-quarters, and began the preliminary examination of our equipment, which hitherto none of us had seen. On the 6th and 7th we sent up all the apparatus, and the photographic camera was erected, but the horizontal axis of Mr. AIRY's stand, which had always been very stiff, now absolutely jammed, and great force was necessary to separate its parts. Fortunately, Mr. HENNESSEY had brought down an artificer from the head-quarters of the Survey, and he re-ground the axis so as to make it work freely. On the 9th all was ready, and the next day we moved into camp on the hill top.

We had had none of the clear frosty weather which had been described to me as usual on the Nilgherries in December. Sometimes indeed it was very fine: the mornings seemed most propitious, clouds often coming on in the afternoon, and this seemed the usual case on our station Dodabetta. The night of the 10th was the first we spent there, and early next morning Captain HERSCHEL and myself were up, with the view of examining μ *Argûs* and focussing, &c., the spectroscope. It was very glorious: as the sun rose we found ourselves over a sea of cloud and mist passing round the shoulders of our hill and shutting out from us Ootacamund and the whole of the lower hills to the west. To us the sky was perfectly clear, except here and there a stray wisp of cirrus: as the sun rose the mists were dispelled, and gradually nearly the whole of the lower clouds dispersed, and we had a splendid day, giving us great hopes for the eventful morning. The night was fine, and continued so till about 2 A.M., when mist came on, and this gradually became rain. When we rose the mist was less thick, and we occasionally saw the stars, but everything about us was dripping wet. As the light broke it became evident that the mist rose to no great height above us, and it was generally so thin that there was no difficulty in watching the progress of the Eclipse, but there were thicker places, and at all times our telescopes were dripping, and the object-glass of mine required frequent wiping to get definition. Through the breaks I could see the sea of cloud far below me as on the previous day, and it seemed to me clear that that was not the cause of our plight: it was the recent rain evaporating from the hill side, and this vapour becoming again condensed in a thin layer as the S.E. wind carried it up the hill side. Under ordinary circumstances the heat of the sun would have dispelled this, but of course the obscuration by the moon counteracted this natural order, and we, looking S.E., only lost the mist a few minutes after totality was over; but before this it had vanished on the Western side

of the hill, and we could see Ootacamund and its lake long before there was a free view where we most desired it.

The observations I shall describe separately. I have only to add, that as soon as possible after the Eclipse, I went down to write my account of our results by the mail leaving the same afternoon, and that all our instruments, &c., were down at our head-quarters and under cover the same evening. I was obliged to leave Ootacamund on December 14th, to catch the steamer for Calcutta; Messrs. HENNESSEY and HERSCHEL left soon after myself, after having packed up everything; and Captain WATERHOUSE remained to bring the instruments on with him.

Before closing this, I ought to mention the great aid given me by Captain MORANT, R.E., Executive Engineer. Some account of observations made by him will be found later: but he also lent me convict labour, and the services of a detachment of the Madras Sappers, who were under his command. I was thus free from the necessity of calling for a considerable number of coolies in a very restricted market, and had soldier assistants on whom we could rely both to help us in setting up and dismantling the instruments, and in guarding them while in position. Captain MORANT also allowed his overseer (Mr. WILLIS) to make all the preparation for work in Dodabetta, and to assist Mr. HENNESSEY during the Eclipse.

SPECTROSCOPE AND GUIDE TELESCOPES.

I had asked Dr. HUGGINS to have two telescopes arranged, so that an observer using one in the usual manner should be able to place the slit of a spectroscope attached to the other on any object which he might desire to have examined. As I purposed moving the spectroscope during the short interval of totality from one object to another, and none of these probably would be very well defined, it seemed to me that an equatoreal mounting with clock work was not necessary, and I very much doubted if one could be got in the short time available. I had seen the efficiency of a wooden stand (somewhat similar in principle to what Dr. PEARSON describes as VARLEY'S) employed by Dr. JANSSEN in 1868, and I looked to getting one of this sort quickly made and mounting on it two telescopes. By the kindness of the ASTRONOMER ROYAL, however, Dr. HUGGINS was able to borrow for me one of the 6-inch equatoreal telescopes provided for the Transit of *Venus* in 1874,

and, in order to adapt this to my views, the counterpoise to the telescope was removed and a second telescope of the same size placed at the other end of the declination axis. So modified, there was some difficulty in making it work as an equatoreal, and it was resolved to let it be used as an alt-azimuth by placing the polar axis as nearly vertical as could be done without levels, &c. The general appearance of the instrument as we used it can be seen from the annexed illustration* (a photograph by Captain WATERHOUSE), and I do not think that we should have gained any thing by more complication, at all events during the Eclipse. A piece of bare granite was surfaced so as to take the base of the stand, and a parapet of turf was built up as shown, to the N.E., and to a lower height on the S.E., as some protection against the keen winds which we might expect. Under the eye-ends of the telescopes a bank of turf was built up to such heights as would enable us to reach our eye-pieces with convenience : that for the spectroscope was adapted only for the time of totality, but I had that at the guiding telescope built high, so that I could watch the commencing Eclipse, and a sapper at hand removed successive layers as the sun rose. I myself took the right hand or guiding telescope, and the duty of selecting objects for examination; while Captain HERSCHEL took the spectroscope. Mr. BURROWS, one of the masters of the Lawrence Asylum, kindly attended to record any phenomena which might require immediate note, and I gave him some, which are, however, of no importance for the purpose of this report, to record during the earlier part of the Eclipse ; but during totality I preferred to note mentally rather than use any words beyond those pre-arranged to be signals between myself and Captain HERSCHEL. I shall now proceed to describe what I saw, and then take up the work of my collaborateur.

Direct Vision.

First, then; I observed the Eclipse from the first contact till totality whenever the Sun was not shut out by clouds. I had intended to have examined those remarkable prolongations of the cusps which frequently appear to be within the Moon's limb, and had hoped that they might be submitted to the spectroscope. I did not, however, see any signs of these till very shortly before totality, when the cusp was already extremely fine. On the cusp I then set the slit of the spectroscope, and I followed it then till the total phase had commenced. I had calculated that the first internal contact would take place some 10° to the south of the Moon's apparent

* See note, p. 32.—ED.

vertex. Some minutes before totality, however, it became evident that the line of cusps would not deviate much from horizontality, and the slit of the spectroscope and wires in my telescope had been shifted. The vertex was very near the point of contact.

In pointing for the spectroscope I had opportunity of seeing the corona well. The eye-piece employed was one with a magnifying power of about 35, and the aperture was reduced to $2\frac{1}{2}$ inches (65 m. m.) by a very loose pasteboard cap, which I had intended to knock off just before totality. I, however, was so employed in following the cusp that I forgot this, and I doubt if I should have gained much: the image was very brilliant, and I find that on a dull foggy morning the pupil of my eye has only $\frac{1}{10}$th of an inch (2·5 m. m.) of diameter, so that with so low a power the greater part of the aperture of the telescope would have been wasted. I was obliged to use a low power, that I might be able to select points for spectroscopic examination in as large a field as possible.

In following the retreating cusp, I saw what must have been BAILY'S beads, but these were clearly small specks of light passing hollows in the Moon's limb, and enlarged by the irradiation of the telescope. I kept one of these some few seconds in the place corresponding to the middle of the slit, and am quite satisfied that there was no running or flowing. When the totality commenced the prominences and chromosphere appeared to me *white*, passing almost immediately into rose, and then to their usual red. There were certainly no green or blue tints either at the beginning or end of totality. The corona was colourless : its brilliancy was greatest near the Moon, and it faded off gradually at some distance: it was of variable width, but I saw no marked line of demarcation between an inner and outer part. The general appearance I thought very much like No. 1 photograph, save that the glare near the Moon was different, and the light extended further, and shaded off more gradually. There were numerous wedge-shaped portions of a grey tint, with their axes nearly radial and darker in tint than their margins. These formed the rifts and the separations of the rays. They did not seem to me to extend down to the Moon, but it must, I think, be evident that the extent of these rifts would vary greatly with the brilliancy of the image. I had occasion to examine the corona at 15′ or 16′ from the Moon's limb, and with this part of it in the centre of the field my impression was that though the brilliancy was markedly decreased, I was not near the limit of coronal light, and I could see the edge of the rift under examination stretching some distance further. I saw no changes in the corona: the rifts I was examining seemed perfectly

steady. One of the parts to which my attention was especially directed was the nearly vertical edge of the rift to the right of No. 1 photograph: the other was a narrow rift very near the apparent lowest point of the Moon which was examined in two places.

The Spectroscope.

The second telescope was adapted to the use of the spectroscope which Dr. HUGGINS took to Oran, and which he has described. The Messrs. GRUBB had provided for it a new compound prism, whose qualities are much the same as those of the most dispersive prism provided by them for the great Melbourne telescope. In this instrument there is a pointer which is visible without artificial illumination, except in a very dark field. It is traversed in the plane in which the image of the spectrum is formed by a coarse screw, and with it is moved the short end of a lever, of which the longer end carries two pricking points, one or both of which can be depressed by the action of a finger so as to prick a record of the position of the pointer on a card; and allow of its being identified, and by its means that of any spectral line which was identical with it when the record was made. The eye-piece took in only a portion of the spectrum, along which it could be slipped by the hand, but there was no means of connecting it with the frame carrying the pointer. It will be seen then that both hands being occupied, one in recording and one in moving the pointer, it became necessary to choose between the loss of time necessary to shift one hand to the eye-piece and recover its position, and the abandonment of all but one portion of the spectrum. Captain HERSCHEL decided on the latter alternative, and confined his attention to the spectrum between B and F. The pointer which came out with the spectroscope only crossed about half the width of the spectrum, and could not without difficulty have been used with a narrow spectrum, except in the centre of the field; the solar lines too as seen in the spectroscope were very markedly curved. Captain HERSCHEL, therefore, removed the pointer, and in lieu of it substituted a sewing needle: by bending this a little and availing himself of the rounding of its point, he was able to secure a sufficient coincidence across a large portion of the field between a line of the spectrum and the edge of the needle nearest the less refrangible end of the spectrum, and thus avoid all corrections for curvature; but, on the other hand, this procedure could not but sacrifice some of the accuracy of which the instrument was capable, and this has helped to make some of the difference between different records of the same lines.

Another small change was that, it having been found that the pricking point was prevented from marking in the middle of its traverse, at some of the settings of the card, additional positions for setting it were made so as not to decrease the possible number of registers.

The spectroscopic focus which had been obtained on the Solar Prominences was verified on the morning of December 10 (astronomical) by a star, and the width of the slit was so adjusted as to show the principal dark lines of the spectrum of the sky near *Sirius* when it was fading out in the morning twilight. At this place the head of the adjusting screw of the slit was marked, and on the morning of the Eclipse this mark was replaced at the position it had occupied the previous day, which can also be identified by its being three-quarters of a revolution from "shut." Captain HERSCHEL also states that b_2, b_3, and b_4 were not separate, nor were D_1 and D_2, but that apparently b_1 was separate from the other b lines and D_3 from D, and this statement will probably give the best idea of the width of opening. The length of the slit was such as to give a spectrum some 18′ wide.

The cusp which I placed in the field (as I have before mentioned) was that to my left or the southern one, and on it Captain HERSCHEL verified the accuracy of accordance between the slit and the corresponding mark in the guide telescope. "While doing this," he says, "I noticed the usual three "bright lines appearing as short projections on the right edge of the narrow "strip of sun spectrum becoming sensibly brighter, and very soon an addi- "tional spike or two appeared. I cannot recollect now *which* lines appeared "first, but after a few seconds I felt impelled to make first a record; and "giving notice that I was about to do so, I pricked down rapidly all that I "could feel sure of. By the time this was done, or very soon after, "the number of short bright lines increased greatly, the strip of sunlight "almost vanishing; another and wider series also appeared on the left. "Just at the moment when (as I suppose) totality occurred, the appearance "was, if I recollect rightly, that of a bright string of coloured *points*, or very "short lines, in the centre of the field, and of a *series of lines* on the left, "extending, where widest, nearly up to the string, the distance from centre "to centre being probably 3′ or 4′. But it is impossible to speak positively of "the succession of simultaniety of appearances in a case like this, when there "is reason to believe that the slit was being rapidly moved along in pursuit of "a returning cusp. Ultimately the spectrum presented was one of numerous, "but not very many, bright lines of various intensity and considerable length. "I was told to record, and I did so: my impression is that I pricked all I

"could see, but there is no time to look about or pay much attention to any-"thing but intersection, where a spectrum of nine or ten lines has to be seized "in as many seconds." It will be evident that Captain HERSCHEL had the spectra of both cusps * of the chromosphere in the field.

As soon as this record had been completed at the place of the Sun's disappearance, I turned the telescopes so as to place the slit on the centre of the Moon. This had been particularly wished by Captain HERSCHEL, and I also was glad of an opportunity of seeing the whole outline of the Moon, and getting a general view of the corona, that I might note any remarkably bright streamers, &c., for special examination. After a careful inspection, Captain HERSCHEL reported nothing visible. I then moved the slit to the nearly vertical edge of a rift, which was very large and conspicuous to the apparent left of the Moon, and placing it about 10′ from the limb, called on my companion to record. He says: "There was but one line in the field, "of a green colour, and pale, but extending all across the field, which I recol-"lected, when I came to make notes, was far from dark, differing decidedly in "this respect from that which I had just before searched." The next point examined was about 8′ from the Moon's limb, and apparently (in the inverting telescope) below the centre, the slit being entirely across a grey partition between the bright rays. This partition was nowhere dark like the rift last looked at, but was much more marked than most of the grey portions of the spectrum. Captain HERSCHEL says: "The next record was precisely the "same, except that both line and field were fainter. In both cases I was "doubtful about recording traces of lines which I fancied I saw in various "places, but it would have been hazardous to stop for them if they really were "there. I have a distinct recollection of a dimly illuminated field, in which "I could see the needle easily; and, when I reflect, I feel convinced that there "must have been diffused light, due to the corona, of considerable intensity; "for apart from the visibility of the needle, the comparatively feeble character "of the single line seen is not in keeping with the brilliancy of the corona as "apparent to the eye."

I now moved the slit on to another part of the same grey space, about double the last distance from the Moon's limb. I still saw coronal light here, though it was faint. Captain HERSCHEL, however, could see no lines, though he saw faint light. Finally, I placed the slit where it was a tangent to the

* Captain HERSCHEL expresses doubts of this, but it is evident that as the cusps closed both must have been within the space subtendent by half the length of the slit.

Moon's limb, close to the place where the Sun would reappear. The following is the account of the end of the Eclipse here seen: "Immediately a number "of bright lines, many of them already familiar, became apparent, I was about "to attempt a final record, when the field began to brighten, not suddenly, but "gradually, and immediately the number of lines increased so greatly, that I "could only look at them; to record was hopeless. The gradual breaking in "of the solar light was no doubt due to the slit being a little way off the "limb." As a matter of fact, the slit was, as well as I could place it so, on the limb of the Moon, and the brightening admits, I think, of another explanation.

I now proceed to the identification* of the lines, in doing which I shall assume that in spectrum 3 (that taken at the first internal contact) C, D, D_3, b_1, and F were present, and correspond with marks on the register card. From these points I proceed by interpolation.

First comes a line between C and D, which I find would, if accurately noted, read 784 of KIRCHHOFF's scale. If this be one of the lines mentioned by Professor YOUNG in his Preliminary Catalogue (*American Journal*, November 1871), then it must be No. 7 of his series, but it very closely corresponds to two strong lines in KIRCHHOFF's chart, and also to the two iron lines 6392·5 and 6399 of ÅNGSTRÖM. The line between D and F is, I find, what would read 1497 of KIRCHHOFF. It is probably the known corona line 1474 K, but it may be worth note that Professor HARKNESS obtained a line corresponding to K 1497 from several spectra of the chromosphere and prominences during the American Eclipse of 1869. In Captain HERSCHEL's corona spectrum No. 5 the noted line corresponds with this in No. 3, and in No. 4 it reads a little higher. Taking into consideration the faintness of the line, and the other sources of uncertainty which I have pointed out, there can, I think, be no doubt that all three are identical.

Near b_1 is a line which is probably a combination of the magnesium lines b_2 and b_4.

Passing on towards F we have a line whose place would be K 1849. This is probably 56 and 57 of Professor NEWTON's Catalogue, corresponding with 1866·8 and 1870·3 of KIRCHHOFF.

* Captain HERSCHEL has furnished me with identifications of the lines he observed. They differ very slightly from these; the position of the line between D and F is numerically different, but we refer it to the same line. Captain HERSCHEL also thinks that the last line is a compound of 59-60-61, of Professor YOUNG, while I have preferred the commoner and stronger line.

Still further on we have a line, whose place reads as K 1988. It seems probable that this is 58 of the Preliminary Catalogue, or K 1989·5, a strong barium line in the solar spectrum, and one which Professor YOUNG seems to have seen somewhat frequently.

PHOTOGRAPHY.

The photographic operations were under the general charge of Mr. J. B. N. HENNESSEY, of the G. T. Survey, with whom was associated Captain WATERHOUSE, for the special purpose of attending to the technical manipulations.

The apparatus was originally intended to have been made in India, and I had intended to borrow a lens from the Surveyor-General's office, but it was very fortunate that Dr. HUGGINS undertook to provide all that was needed, for unforeseen difficulties arose, and I was unable to give such constant attention as was necessary to the details. Dr. HUGGINS was assisted by Mr. BROTHERS, of Manchester, whose experience of the Eclipse of 1870 was valuable, and who kindly fitted up a box of chemicals and apparatus for us.

The lens employed was one of DALLMEYER'S largest "Rapid Rectilinears" of 4 inches (10 c.m.) aperture, and about 33 inches (83·7 c.m.) equivalent focus. This was attached to a cylindrical metal camera, which was mounted on an equatoreal stand, and a clock was provided to keep the camera automatically up to the object to be photographed. The cradle carrying the polar axis and clock had a slight rocking motion on the pillar, which gave sufficient adjustment for latitude, while for azimuth the whole apparatus, pillar and all, had to be moved. By fixing approximately the meridian with a compass, it was found that the bringing of the polar axis into position with a sufficient accuracy was not very difficult.

The clock was that belonging to Mr. AIRY'S instrument, which, not being wanted there, was made available for the photographic apparatus. When it was unpacked it was found that the steel axes were a good deal rusted, but fortunately none of the working portions were damaged, and when cleaned and put together the clock seemed to go well and pretty regularly; but it stopped occasionally, without apparent cause, and on one occasion it was found that a clamp, binding together two parts of a connecting rod, slipped, and

allowed the clock to go without acting on the camera. It was hoped that sufficient precautions had been taken to prevent the recurrence of any accident of this sort during the Eclipse. One has, however, only to look carefully at photo. No. 6 to see that during the 20 seconds of exposure that were given to it, the clock was not doing its work, and comparison of the trace of the northern prominence with the Moon's diameter shows that, in fact, the impression is the whole effect of diurnal motion.

The camera was furnished with 6 dark slides, each to hold a plate 5″ square, and the whole had been well considered with the advantage of Mr. BROTHERS' advice, so that the changes could be rapidly made.

The stand stood on a bare surfaced rock, and the whole instrument was covered by an observatory tent.

We had intended to use Thomas' photographic tents for the operations of preparing the plates and developing the pictures, but finding that there would be facilities for building a hut for the purpose, and considering the exposed summit of the hill, the entire want of shelter for the tents, and the great difficulty of illuminating them artificially, it was determined to make a hut of bamboos, wood, mats, and turf, which should hold all the materials, and at the same time serve as a dark room This was done by Mr. WILLIS. The floor was about $12' \times 6'$ and there was a good broad shelf at each end, one for sensitizing and one for developing the plates, while a narrower shelf ran along the north side of the room, and carried the fixing bath, washing troughs, &c. The inside was well lined with matting to keep away the dust. A pane of yellow glass was placed in the door, but it was thought necessary to provide candles as well for illumination.

I had originally intended that the photographs should be taken by Mr. DE LA RUE's procedure, with similar chemicals to those we had used in 1868. I had abundant reason then to be satisfied with the delicacy of detail, and I felt that now with so small an image much might depend on magnifying. With this view I had had some nitrate of silver fused; and a considerable quantity of water was distilled from a solution of potassic permanganate in a glass retort, into a glass receiver, whence it was transferred into clean glass bottles. Captain WATERHOUSE and I tried a number of experiments with the various chemicals, of which I may give the following general results.

It was very difficult to make a bath which should *certainly* work cleanly in Mr. DE LA RUE's process, and was extremely easy to make this preliminary when using a bromo-iodized collodion. The deposit from simply iodized collodion with a pyrogallic acid developer was unquestionably the finest, it

gave the most delicate detail, and admitted best of being magnified, while the deposit got by a bromo-iodized collodion, and an ordinary protosulphate of iron (ferrous sulphate) developer was worst; but by using sugar freely in the iron-developing solution (an expedient I have adopted for years) the deposit on bromo-iodized collodion became very nearly as fine as with pyrogallic acid, while the whole procedure became simple and certain. At the same time it was evident, as I had long known, that the use of sugar enabled objects having varying degrees of illumination to be depicted in some detail. I was however, most unwilling to give up Mr. De La Rue's process, which I had tried, and I believed that by timing the exposures suitably we should get all the grades of the corona, not indeed on one plate, but among the plates. When we reached Ootacamund, however, and began experiments, we were met by the bath difficulty at once, and this was only got over partially by re-distillation of the water. Captain Waterhouse, therefore, strongly urged that he should use the less difficult mode of proceeding with which he was more familiar, and which, especially with the modification of adding sugar to the developer, brought out a greater range of intensities: and this was resolved on.

The following, then, was the working method:—

The collodion was partly Thomas' and partly a mixture of equal parts of Thomas' and Mawson's, in both cases bromo-iodized.

The baths contained about 30 grains of nitrate of silver per ounce (69 per cent.), and was as nearly neutral as possible.

The developer had the following constitution:—

Ferrous sulphate	15 grs. per oz.	3·44	per cent.
Table sugar	15 ,,	3·44	,,
Glacial acetic acid*	10 ,,	2·29	,,
Spirit of wine	15 minims ,,	3·44	,,

The negatives were not intensified, but each, as developed, was placed in a dish of water till its turn came to be fixed in a strong bath of sodic hypo-sulphite.

In order to secure the comparison of these photographs with those of others, one corner of each plate was marked, they were all placed similarly

* I am very averse to the use of acetic acid. It it quite possible to use 50 grains of ferrous sulphate per oz. with a suitable amount of sugar and without acid; and I believe the acid restrains the faint impressions more than those of stronger light.

in the slides, and finally a seventh plate, similarly marked, was placed in the camera, and a declination circle was depicted on it by traversing the camera rapidly past the sun with a small stop in the lens.

A good deal of time was spent on the two days before the Eclipse and, finally, on the morning itself, in rehearsal of their parts by those who were to share in the work. Mr. HENNESSEY undertook the making of the exposures and recording the times, &c., from Mr. WILLIS' counting off a chronometer, and Captain WATERHOUSE, who prepared and was to develope the plates, took the duty of changing them rapidly. The proceedings began, notwithstanding the bad promise of the weather, by commencing the preparation of the plates some 20 minutes before the calculated time of totality. While Captain WATERHOUSE was busy with this, Mr. HENNESSEY carefully focussed on the fine cusps, and all being ready the party took their positions about five minutes before the commencement of the total phase, in positions which will be seen from the accompanying photograph.* A few seconds before totality, Mr. WILLIS began calling the seconds, keeping his attention fixed on the chronometer face; when the sun disappeared, he was warned, and began to count, and Mr. HENNESSEY recorded the moments at which he opened and closed the lens on a card fastened on the back of his hand, the seconds being counted from the commencement of totality.

I had arranged that the exposures should be in succession 5^s-10^s-15^s-15^s-10^s-5^s, on the supposition, of course, of a clear sky. The state of the weather, however, put out of the question the possibility of connecting the duration of the exposure with the amount of detail on the plate; while, on the other hand, the adherence to our programme would have risked some plates being entirely under-exposed. Mr. HENNESSEY, therefore, resolved to abandon all rule, and to judge of the amount of exposure by his estimate of the intensity of the light. The exposures were then counting from the beginning of totality:—

No.	1	exposed at	4^s,	shut off at	19^s,	Exposure	15^s
,,	2	ditto	34	ditto	44	ditto	10
,,	3	ditto	55	ditto	63	ditto	8
,,	4	ditto	74	ditto	80	ditto	6
,,	5	ditto	88	ditto	93	ditto	5
,,	6	ditto	103	ditto	123	ditto	20

The light was only just shut off from the last plate as the Sun reappeared

* See note, p. 32. ED.

Description of the Photographs.

From the original photographs Captain WATERHOUSE has made some positive transparencies on glass which give a good general idea of them. I take, however, the following descriptions from the original negatives, some of which give a great deal of detail which is lost in copying.

No. 1 is perhaps the most perfect. It had an exposure of 15 seconds near the commencement of the Eclipse. I have found that the middle of the Eclipse was at 14h. 27m. 4s. Greenwich mean time according to the tables. Mr. HENNESSEY, who had most facilities for marking the duration of totality, gives it as a little more than 122 seconds. From these data, and the reckoning formerly given, I reckon that this plate was exposed from 14h. 26m. 7s. to 14h. 26m. 22s. of Greenwich mean time. The disk of the Moon is surrounded by a narrow very luminous border almost indistinguishable from the prominences, but whose inner edge is sharply defined by the Moon, except in one or two places, and whose outer one varies very much in distance from this, and is much less sharply defined. There is much encroachment of light on the dark surface of the Moon, and this is greatest at the places of prominences, and especially at the lower part of the disk where the solar edge is nearest. Here the encroachment nearly obliterates the disk in some places, and presents a very marked outline; here, too, the brilliant band is brightest and widest, and its outer edge most defined. Outside this is the corona, at the bottom are seen several rays with ill-defined edges. One of these to the right (S.) of lowest point is markedly curved; the outer end pointing S.W. The great rift to the south, and a less marked one to the north, each have a prominence at the base;—close to the vertex is seen the small rift which was spectroscopically examined. There is structure clearly seen in the whole of the corona; and, except in the case of the curved ray of which I have spoken, it seems to me that there is a tendency to radiate from prominences. Some of the longest rays may be faintly traced to a distance of $\frac{3}{4}$ths of the Moon's diameter.

No. 2.—It is evident, on looking at this, that the chemical action has been much less: the encroachment of the general light on the lunar disk is much reduced, while that of the prominences is more conspicuous. The broad band of light at the bottom of No. 1 giving an appearance of a well defined portion of corona has disappeared, and the light now decreases

gradually from the Moon's edge. The outline of the lower edge of the south rift is shown as more curved; but comparison shows that this is not so much a real change of form, as the result of the fainter portions being less depicted. The radial structure of the corona is as marked here as in the last photograph, and the same tendency to stream from prominences may be recognised with perhaps more facility. The exposure may be considered to have lasted from 14h. 26m. 37s. to 14h. 26m. 47s. of Greenwich mean time. There is a good deal of fog about the plate.

No. 3.—Here the active effects are evidently between those in Nos. 1 and 2; the outline of the south rift is restored very much to its appearance in No. 1; and the photograph otherwise requires little remark. It may be considered to have been exposed from 14h. 26m. 58s. to 14h. 27m. 6s. of Greenwich mean time.

No. 4 is a good deal like No. 2, save that the lower prominences, being more covered, the glare there is much less. Placed on a dark ground, and viewed as positives, these two photographs are very similar; viewed as transparencies, No. 2 has decidedly more detail and extent. It may be considered as having been exposed from 14h. 27m. 17s. to 14h. 27m. 23s. of Greenwich mean time.

No. 5.—This has less detail than any of the preceding photographs, and there is a want of sharp definition, showing that there was some motion of the camera relative to the object. This may be due to the action of the clock ceasing, as I have mentioned it did during the exposure of plate 6, and I am disposed to think it is so, but the short exposure makes the effect small, and leaves this photograph available as evidence of the general permanence of the corona during totality. It may be considered as exposed between 14h. 27m. 31s. and 14h. 27m. 36s. Greenwich mean time.

No. 6.—As I have mentioned before, the clock manifestly ceased acting during this exposure. Looking at the upper edge one sees the succession in which the peaks of the chromosphere appeared, and it is evident that a momentary exposure would have sufficed for depicting these. Mr. HENNESSEY expresses himself confidently that the mist was passing in a continuous stream of varying, but generally diminishing, density: a dense portion must have been present at this time, or there would have been considerable marks of the corona instead of very slight traces.

MISCELLANEOUS OBSERVATIONS.

Polariscope.

I had intended to observe the polarization of the coronal light myself, but was prevented from doing so, and at the time I did not think it of any importance; but, as anomalous results have been obtained, I think that I should include here the following note from Mr. J. BROUGHTON, B. Sc., who observed with a SAVART'S polariscope in his hand:—"No polarization was "observed near the Sun until the instant of totality, when the bands instantly "and strongly appeared with the light of the corona, &c. I could see no "change in the polarization in about half a degree from the Sun, though of "course the light was fainter. The plane of polarization was that of the "vertical, through the Sun's centre (*i.e.*, the bands were quite perpendicular to "the eye) when strongest. I had previously set the polariscope by the sun- "light reflected from the surface of water. I could see no faint bands by "looking at the moon's disk." This, so far as it goes, is entirely confirmatory of the observations of 1868. It would have been more satisfactory, looking to the statements of other observers, if Mr. BROUGHTON had chosen some plane not vertical for examination, but he could not of course foresee. Mr. BROUGHTON observed at Dodabetta.

Direct Vision.

Captain MORANT was supplied by me with a small reconnoitring telescope by DALLMEYER, of $1\frac{3}{4}$ inch (45 m. m.) aperture and 14 inches (35·5 c. m.) focus, giving with a power of 15 a singularly beautiful image. It was mounted on a stand. His instructions were to endeavour to make two sketches, and generally to attend to the directions to direct vision observers in the instructions of the B. A. Committee. Captain MORANT has furnished me with two sketches of the total phase, and notes answering the questions, to be found in the Instructions.

Captain MORANT'S sketches show very marked changes in the corona, but this hardly coincides with the account he gives. He says, "there seemed "a considerable general change over the whole corona, which made it difficult "to draw its shape, but I observed no marked change of any kind. The rays "in some places disappeared, and in others fresh ones come into view."—"Of

"the two dark rays or rifts (these are clearly rifts) the one to the right (S.), "looking at the drawing, seemed to slide lower down towards the bottom of "the moon as the Eclipse advanced. The other, or left-hand rift, did not "change." The eye-piece was, of course, an erecting one; and if the corona be dependent for its appearance on the Sun alone, then this description must be a mistake. Captain MORANT describes the corona as free from colour, and the dark interspaces as of a sepia tint. Of the south rift, he says that it "unmistakeably extended down to the Moon. The other seemed to stop "short just about the more brilliant white ring round the Moon." Captain MORANT also says that he saw a blaze of light both at obscuration and re-appearance of the Sun.

Each of my assistants has given me notes of his view of the corona. Of course in each case these views were hurried, but the accounts are not without interest. Mr. HENNESSEY says: —"Though I was debarred from looking "steadfastly at the appearance of the eclipsed Sun, I yet took every opportunity "of glancing at it, and did so for perhaps two or three seconds at a time. "Thus viewed the general outline of the corona looked like a sand-glass or the "figure 8, in which comparison the two re-entering angles must be understood "as much exaggerated beyond the reality. There were no conspicuous "prominences, but of those visible the ones about the vertex were the strongest. "I saw no rays (or streamers) stretching greatly beyond the Moon, and so far "as I could estimate the entire phenomenon was included in an annulus of "half the Moon's diameter around her edge. In brief, what I remember to "have seen during totality is exhibited in the negatives 1 to 4; they contain "details of which I was unconscious in making my hurried glances at the light, "but I am not aware that the negatives are deficient in any respect."

Captain HERSCHEL says: "During the interval between record No. 6 and "No. 7 (both blank)—at least I believe it must have been then—I had time to "look up at the Sun. The sight can never be forgotten; whether it was that "my eyes had been *calmed* by looking into a nearly dark field, or that the short "time—not more than a very few seconds—which was granted me, fixed the "impression received very securely, I cannot say, but the picture formed on "my retina remains singularly clear and well-defined. It may be that I had "allowed myself to doubt too much the extraordinary spectacle which so many "have endeavoured to reproduce in pictures. Very likely, too, on this occasion "it was especially magnificent, owing to our great height and the intrinsic "clearness of the atmosphere, the driving mist close to us notwithstanding. "At any rate, what I did see was singularly plain and impressive. The corona

"was evidently, to my eyes, an assemblage of distinct and well-defined groups "of rays, of which the strongest ones seemed to start directly from the central "disk, so that the so-called rifts were only the interstices between the bundles "of rays. The longest of the latter seemed to extend about one and a half "diameters from the dark disk. I should add that the photographs which I "have seen do not recall, in any satisfactory way, the impressions which I "received during those three or four seconds, the individual separate character "of the ray-groups being almost entirely lost."

Captain WATERHOUSE says:—"The sum of my observations is that the "first four photographs very fairly represent the Eclipse as it appeared to me, "both in size and general appearance. I saw no great changes in the form of "the corona till perhaps towards the end, but of this I am not certain. I "recollect carefully observing the general appearance of the phenomenon for "some time, so that I might, if possible, make a sketch of it afterwards. I "noticed particularly the triple, crown-like appearance of the vertex, and the "two large rifts at the sides almost exactly as represented in the photo-"graphs, and had I tried to make a drawing I should have drawn much the "same."

Integrating Spectroscope.

Captain HERSCHEL has handed me the following note on observations made by Colonel SAXTON, whom he trained himself, with an adaptation of the Royal Society's telescope and spectroscope:—

The Royal Society's equatoreal was adapted as an integrator by inserting a double convex lens (1·8 inch in diameter) of $5\frac{1}{2}$ inches focus into the spectroscope tube at about 2 inches beyond the slit, and then sliding the tube until the distance of this lens from the object-glass of the telescope was equal to the sum of the focal distances. Thus the slit received the rays from the object as the eye would receive them in like case, in parallel pencils; and could view (so to speak) just what the eye in its place could see, this was found to be a field of about $60'$. Now, the cotangent of half this (the radius of the field) is 115, and the magnifying power being inversely as the focal distances, or $62\frac{1}{4} : 5\frac{1}{2} = 11\frac{1}{3}$ nearly, this field was presented to the slit under an angle of $2 \cot^{-1} \frac{115}{11\frac{1}{3}}$ or $2 \cot^{-1} 10 = 11°24'$. But the collimating lens of the spectroscope subtends only an angle of $10°$, consequently the outer portions of this field were not received through the centre of the slit, but, in part, through the ends. It seems the more necessary to go into this calcula-

tion, as the integrating spectroscope has not been so minutely described hitherto, as to put its essential features beyond doubt. The principal of these seems to be, that every part of the area whose light is to be integrated shall—or should, if the slit were a pinhole only—throw its slitful or pinholeful of rays on to the collimating lens. This would be perfectly effected without any lenses in front of the slit, but the area gathered from would then be needlessly large, so that a magnifying power sufficient to increase the desired area, to that which the collimating lens can receive, is requisite. But, given the desired area, and the aperture of the lens, and consequently the power required, it is not clear that there is advantage in using a larger telescope.

If this conclusion is correct, the failure of the integrating spectroscope on this occasion is accounted for. If not, the cause must be sought in the undoubted fogging of the prism, and the narrowness of the slit.

All the adjustments were performed by myself during the hour preceding the Eclipse. The clock work—adjusted to solar motion—kept the telescope directed at the Sun's centre. The slit was opened to the extent necessary to run the two upper *b* lines into one band, and I satisfied myself that the eye-telescope was suited to the observer. The following is his report, written down while standing at the instrument after totality:—

"The dark lines C D and F at totality changed suddenly into bright lines. K 1474 did not appear for some time, and when, or before it did, C D and F had faded away. It remained for a short time only, and then, just before the light returned, C D and F again for a moment became bright before changing to dark lines."

(Sd.) G. H. SAXTON, *Colonel.*

A note was afterward added explaining the use of the letter D, and the statement about its inversion, as recognised inaccuracies. Colonel SAXTON also, adds that "the dark lines before and after totality were numerous and "distinct, the principal ones well marked." This must be read, not as conflicting with my own statement regarding the width of the slit, for Colonel SAXTON's acquaintance with the solar spectrum was recent, but as showing

only that the slit might have been wider with advantage. He goes on to say, "throughout the observations, with dark as well as light field, the cross-"wires were easily seen, but I did not notice any trace of any bright line, "except the above." I further ascertained from him that the said cross-wires, which I had carefully placed in the position due to K 1474 appeared to intersect that bright line truly.

The meagreness of the positive results in this instance renders it unnecessary to do more than allude to the preliminary training which Colonel Saxton had imposed on himself during the previous day and night to enable him to commit to memory, and paper, an accurate picture of the compound spectrum, which it was thought might be presented. I have every reason to believe, from the experiments tried, that a very trustworthy record would have been produced. As it is, there is nothing positive but the (apparently) continuous spectrum, and the single coronal line. It is curious that this instrument has again refused to show more than the three principal prominence lines.

When totality was over, I examined the direction on the Sun's centre, and found it correct. I also wished to satisfy myself as to the distinctness of the dark lines, but found that the fog had settled on the prism so much as to completely spoil the spectrum.

Colonel Saxton did not remark any dark lines during totality, although he had been cautioned that their visibility, if present, should be noted.

CONCLUSIONS.

I have now described the data procured during the late Eclipse, and I proceed to say what I think these lead us to believe.

It will be remembered that Kirchhoff ascribed to the Sun a very extensive atmosphere, consisting of a great number of mixed glowing vapours, and that he ascribed the dark lines of the solar spectrum to the elective absorption of these vapours acting on white light coming from a solid or fluid nucleus. The Eclipse of 1868, and all following observations, have shown that at a height of a very few seconds above the visible disk of the Sun the presence of any ordinarily visible vapour or gas, except hydrogen, is not constant, and we have

also learnt from the researches of Mr. LOCKYER and Dr. FRANKLAND that the hydrogen which surrounds the visible Sun is in a state of great tenuity. Even at the base of the chromosphere Mr. LOCKYER only occasionally found lines indicating other vapours than hydrogen and that indicated by the line D_3, and it seemed that we were precluded from seeing the actual evidence of heavy vapours, and thus proving their presence directly. Father SECCHI, indeed, of Rome, claimed to have seen a white continuous spectrum at the base of the chromosphere, and Mr. LOCKYER, on one occasion, saw many bright lines at the foot of a prominence, but these were isolated observations, and no small interest was, therefore, excited by the announcement that Professor YOUNG and Mr. PYE had at the moment of totality in the Eclipse of 1869 seen all the FRAUNHOFER lines in the spectrum reversed. If this were confirmed, it demonstrated the constant existence of a layer of vapours of various metals which had hardly been seen at any other time. Until a few days before this Eclipse, I was unaware that any even approximate confirmation of these observations had been obtained. Captain HERSCHEL's observations at the close of totality, with those made elsewhere to the same purpose, will have set this question at rest, and it is easy now to see why the problem was apparently so difficult before, and how we should now attempt to solve it so as to observe many of the lines, and identify them at our pleasure. The image of the Sun, as seen even in the best telescopes, is not mathematically accurate: the true edge is surrounded by a narrow fringe of light, caused by the diffraction of the object-glass, which has no absolute edge, but fades off very rapidly, giving, even under favourable circumstances, the appearance of a defined boundary. It is never wide, but, small as it is, it suffices to cover the base of the chromosphere, and blot out the light which would otherwise give evidence of the heavy vapours. This fringe cannot be entirely removed, but it can be decreased in width by enlarging the telescope, and still further by increasing the dispersion of the spectroscope. To those who have the means of doing this the further examination of the chromosphere must be left unless photography can be brought to our aid.

In my report on the Eclipse of 1868 I expressed my belief that the corona is the comparatively cold atmosphere of the Sun, shining mainly by reflected light. It will be remembered that I then, as well as several observers since, saw a faint continuous spectrum without any lines. It has been shown since that there are some bright lines pointing to a gaseous constitution of the corona, and to a considerable heat, but the number of the purely coronal lines has not been agreed on. I am not aware, from the data to which I have

access, if observers have uniformly noted how the points of the corona under examination by them were situated, and it seems to me improbable that, if directing for themselves, they should always have paid sufficient attention to this point. It must be evident that with a nucleus giving a continuous spectrum; a chromosphere, absorbing below, and radiating from its upper surface, definite lines of light; and coronal substances, which, while giving out bright lines which are peculiar to them, also reflect what light falls on them; the visible spectrum of the corona must, if we could see it in all its detail, be very complicated, and depend on the position of the places observed.

For some short distance from the chromosphere (in which term I include the prominences) we should probably have the light from it predominant; then, in passing from the Sun, we should first reach a place at which the illumination from the photosphere would equal and then overpower that from the vapours of the chromosphere. In all this portion of the corona the distinctive coronal lines might be little conspicuous, and at a greater distance it is possible that, on the one hand, they would become the sole conspicuous objects; while, on the other, if the outer layers of coronal matters were so cooled locally as to cease to show their lines, the sole remaining light might be that of the Sun nearly as we see it, but very faint.

In 1868 I observed the spectrum of the corona near the vertex of the Moon, but at some distance from the chromosphere. In this case it seems to me probable that the predominant light was solar, that the light from purely coronal matter and hydrogen was not conspicuous, and even this was diffused by the opening of the slit. On the present occasion the outer layers of the corona were alone observed, the object being to get the coronal lines. The observations show that K 1474 is the *sole* real coronal line seen. Captain HERSCHEL's observation that it crossed the field with the slit across the edge of a rift would seem to point to a marked difference between its origin and that of most of the light. Clearly the source of the green line extends where the general light does not. The rifts then would appear to arise from defect of the continuous, or solar, light, and not from the absence of what may be called the specific coronal substance giving the green line. Close to the Sun, at the commencement of totality, this line was seen along with some of the chromospheric lines, but when the Sun was left it remained alone. It was accompanied by a continuous spectrum, which we now know from Dr. JANSSEN's observations is in reality discontinuous, being marked by dark lines which can only be seen with difficulty even when the light is far more

plentiful than we had it. It is also evident, from Captain Herschel's account, that there were probably other faint lines.

Spectroscope and polariscope have so far agreed in assigning a solar origin to the main phenomenon of the corona; and, if we examine the photographs, we shall have the same result. It is quite impossible not to connect the south prominence with the corresponding rift, at whose base it lies, and whose sides clearly in a general way radiate from it. A comparison of No. 1, and the later photographs, shows that the connection lasted, and that, in fact, the Moon passed over the corona. Nos. 1 and 3 do not show any changes in the forms and positions of the portions of the corona; and an examination of the later photographs, Nos. 4 and 5, though the definition is not so perfect, quite supports this. That on the true solar corona is superposed an atmospheric phenomenon is probable enough: but, as I said in 1868, the corona is solar. It is the atmosphere of the Sun in its colder parts. It is, indeed, to some extent self-luminous, but mainly it shines, as I reported in 1868, by reflected light.

MM. Janssen, Lockyer, and Respighi, have all found the spectrum of hydrogen extending far above the chromosphere and prominences. I do not wish the statements as to the probable spectrum near the chromosphere to be considered as explanatory of this. In fact, I have pointed out, in 1869, that the visible limit of chromosphere and prominences could not be that of hydrogen. So far as I then knew none was *seen* above this limit; now it has been seen, and it appears beyond doubt that hydrogen, still retaining heat enough to have its distinctive lines visible during an eclipse, but not hot enough to show them, as the prominences do, in the full blaze of sunlight, is present in the lower strata of the corona mixed up with the matter which gives the peculiar green light.

The following, then, seems to be the constitution of our Sun. There is a nucleus which gives out continuous white light like solid or liquid bodies, and even dense gases: surrounding this is a layer of heavy vapours, intensely heated, but far less so than the nucleus; in which, if a state of equilibrium could exist, the heavier vapours would be lowest. Above this is a layer of glowing hydrogen of very slight density, accompanied by that gas which gives the line D_3. Still further up these gases in a cooler state become mixed with what gives out the green line K 1474; and, lastly, that alone seems to remain.

Of the solar nucleus we know little certainly, possibly we never shall know much, as it is almost hidden from our view, but we do know that its

temperature is so high that we have reason to believe that unless subjected to enormous pressure every terrestrial element would be vapourised. It has been estimated in millions of degrees, but such statements can convey no intelligible idea. We do not know anything of the substance producing the chromospheric line D_3. Professor RESPIGHI'S observation at Podoocotta would go to show that it is inseparable from the hydrogen of the chromosphere. The substance, however, producing the green line K 1474, is one of the most interesting. We not only meet the evidence of its existence in the Sun, but when the higher layers of our own atmosphere are reached we meet, at the great height at which Auroras take place, a substance which gives out a light apparently identical, and again ÅNGSTRÖM and KIRCHHOFF have assigned the power of giving this line to the vapour of iron. It seems nearly impossible that at the low temperature which we know must exist in the upper strata of our atmosphere there can possibly be iron vapour. Is it possible that iron possesses the property of occluding the gas whose distinctive line is K 1474? If it be so, this gas must be under ordinary circumstances of temperature and pressure almost immeasurably rare.

ADDENDUM TO REPORT ON ECLIPSE.

I send herewith a paper showing the reduced measurements of photograph No. 1, which were made in the summer of 1872 by Mr. DE LA RUE and myself. Both No. 1 and No. 3 were measured, the results being reported in a paper printed in Vol. xxxiii. of the *Monthly Notices*, p. 23. I have reduced these into arc to give some notion of the dimensions of the corona. The augmented semi-diameter of the Moon has been obtained from the *Nautical Almanac* data, and furnishes a scale by which the linear measurements have been converted into subtended angles.

As regards the probable errors of these results. The vernier of the micrometer reads to 0·001 in., a quantity which can be well read without glasses beyond what are necessary to give clear vision. Certainly 0·0002 in. could be seen in the microscope, and in such an intersection as that of the Moon's limb the error mainly arose from the vernier, and is probably not greater than $6''\cdot5$ the value of 0·001 in. But when we deal with such an object as the ray H, which fades away with ill-defined outlines, I must own

that I should be unwilling to estimate the probable error in distance at less than 60″, and it may be more.

In the case of position-angles. The probable error depends on the distance of the point measured from the Moon's centre, on the inclination at which the sides of a rift or flame meet, and on the way in which the edges are shaded so that it is more difficult to estimate this. The angles to the re-entering angles of rifts are much better than those to salient points of the corona.

I will only draw attention to the greatest distance to which the rays extend, and its near coincidence with the estimate made by Captain TUPMAN as to the same amount. I think we may conclude that this picture represents nearly all that was telescopically visible to Captain TUPMAN.

TABLE OF MEASUREMENTS OF PHOTOGRAPH No. 1.

Diameter 0°—180° 0·3135 in. 90°—270° 0·3111 and 0·3113.

Mean Diameter 0·3123 in. = 33′ 46″·8.

0·001 in. = 6″·49.

Mean Reading of Centre = 2·037 in.

Do. Limb = 1·881 in.

Position-Angle.	Nature of Object.		Reading.	Distance from Centre.		Distance from Limb.	
				Inches.	Arc.	Inches.	Arc.
° ′			in.	in.	′ ″	in.	′ ″
3 40	Tangent to Lump ...		1·888	0·149	16 7	−0·007	− 0 45
	Tangent to Encroachment		1·907	0·130	14 4	−0·026	− 2 48
5 0	Centre of Rift	A	1·862	0·175	18 58	+0·019	+ 2 4
	Do.	A′	1·845	0·192	20 46	+0·036	+ 3 54
	Do.	A″	1·774	0·263	28 27	+0·107	+11 34
19 46	Point of Flame	B	1·731	0·306	33 6	+0·150	+16 14
33 20	...	C′					
36 55	...	C	1·709	0·328	35 29	+0·172	+18 16
43 0	Rift ...	α	1·754	0·283	30 36	+0·127	+13 44
53 40	Flame ...	D	1·646	0·391	42 18	+0·235	+25 25
58 55	Rift ...	β	1·825	0·212	22 56	+0·056	+ 6 7
		β′	1·850	0·187	20 14	+0·031	+ 3 22
61 24	Flame ...	E	1·669	0·368	39 48	+0·212	+22 56
82 0	...	F	1·794	0·243	26 17	+0·087	+ 9 25
86 0	...		1·681	0·356	38 31	+0·200	+21 38
91 14	...	G	1·609	0·428	46 18	+0·272	+29 25
98 54	...	H	1·500	0·537	58 5	+0·381	+41 13
			1·462	0·575	62 13	+0·419	+45 19
102 0	Rift ...	γ	1·827	0·210	22 45	+0·054	+ 5 51
109 7	Flame ...	I	1·507	0·530	57 20	+0·374	+40 27
112 8	Do. ...	I′	1·680	0·357	38 37	+0·201	+21 45
118 44	Rift ...	δ	1·835	0·202	21 51	+0·046	+ 4 59

TABLE OF MEASUREMENTS OF PHOTOGRAPH No. 1 (*cont.*)

Position-Angle.		Nature of Object.		Reading.	Distance from Centre.		Distance from Limb.	
					Inches.	Arc.	Inches.	Arc.
°	′			in.	in.	′ ″	in.	′ ″
124	46	Base of Curved Flame	ε	1·847	0·190	20 34	+0·034	+ 3 41
126	40	Flame ...	K	1·783	0·254	27 29	+0·098	+10 36
131	45	...	L	1·786	0·251	27 9	+0·095	+10 17
136	42	...	M	1·684	0·339	36 40	+0·197	+21 19
142	7	Depression	ζ	1·744	0·293	31 42	+0·137	+14 49
			ζ″	1·781	0·256	27 42	+0·100	+10 49
154	40	Flame ...	N	1·705	0·332	36 4	+0·176	+19 2
180	2	Hollow ...	η	1·853	0·184	19 14	+0·028	+ 3 2
190	17	Flame ...	O	1·740	0·297	31 8	+0·141	+15 15
201	48	...	P	1·731	0·306	33 6	+0·150	+16 14
216	30	...	Q	1·678	0·359	38 50	+0·203	+21 58
220	53	...	Q′	1·635	0·402	43 29	+0·246	+26 37
228	41	Rift ...	ϑ	1·846	0·191	20 40	+0·035	+ 3 48
232	33	Flame ...	R′	1·780	0·257	27 48	+0·101	+10 56
233	25	...	R	1·723	0·314	33 59	+0·158	+17 6
237	4	...	S	1·728	0·309	33 26	+0·152	+16 27
				1·696	0·341	36 53	+0·185	+20 1
250	26	Flame ...	T	1·659	0·378	40 53	+0·222	+24 1
250	26	Do. ...	T′	1·718	0·319	34 30	+0·163	+17 38
253	22	Rift ...	ι	1·813	0·224	24 14	+0·068	+ 7 21
263	40	...	U	1·642	0·395	42 44	+0·139	+15 2
274	23	...	V	1·558	0·479	51 49	+0·323	+34 56
281	58	...	W	1·624	0·413	44 41	+0·257	+27 58
289	50	...	X	1·606	0·431	46 37	+0·275	+29 45
294	47	Top of Rift	λ	1·813	0·224	24 14	+0·068	+ 7 21
295	39	Bottom of Rift	...	1·864	0·173	18 43	+0·017	+ 1 50
300	0	...	Y	1·674	0·363	39 16	+0·207	+22 24
329	20	...	Z	1·775	0·262	28 20	+0·186	+20 8
335	46	...	Z	1·678	0·359	38 50	+0·203	+21 58

APPENDIX A.

REFERRED TO IN THE FOREGOING REPORT.

Memorandum on proposed Observation of the Total Eclipse December 11–12, 1871, *with Estimate of probable Cost, by* Lieutenant-Colonel J. F. TENNANT, R.E., F.R.S., &c.

Since the great Total Eclipse of August 17–18, 1868, two others have occurred, which have been watched by European and American Astronomers, namely, in August 1869, and December 1870.

The shadow track in the former crossed the whole North American Continent, from Behring's Straits to the neighbourhood of Cape Hatteras. The observers were naturally mostly American and Canadian, and the instruments were mostly supplied from the various observatories. None of these gentlemen had shared in the observations of 1868.

In 1870 the shadow track passed through the South of Spain, Algeria, Sicily, Greece, and Turkey. The observers were mainly European, of whom M. JANSSEN was the only one, I believe, who had been concerned with the Eclipse of 1868; but there was an American party comprising observers of 1869.

The observers of 1869 had not a full knowledge of the result of 1868, some of which, indeed, they misinterpreted. The gaseous constitution of the protuberances had already been fully confirmed by the discoveries of LOCKYER and JANSSEN, and the labours of many who had followed in their steps. Our observations of the corona were, however, in some respects disputed. It was alleged that the light of the corona was not polarized; and while the freedom of the corona spectrum from dark lines was confirmed, some faint bright ones were seen in it which had escaped the observers of 1868.

In December last this existence of bright lines was confirmed. Several reasons have been suggested for their having escaped me in 1868, but none of them seem to me satisfactory, nor do they meet the fact that observers are not agreed as to the number of the lines. The polarization of

the corona light found in 1868 is confirmed; and it appears to be clear that the tests employed by the American observers of 1869, as well as in previous cases, were not so sensitive as that I selected, and which was also supplied to Lieutenant CAMPBELL and to Mr. POGSON's party. We had other tests, but the preference we all gave to SAVART's has been abundantly justified.

There is, however, new matter in the last Eclipse. First and most important is the discovery by Professor YOUNG (of the United States), and by Mr. PYE, of the very thin stratum of the heavy vapours, which theory led us to believe must exist. I have no doubt that it can always be seen under suitable circumstances (though M. JANSSEN expressed himself confident that it could not have escaped him in 1868), but those circumstances have yet to be determined; and to do this, seems important. Secondly, in December 1870, were obtained, for the first time, really satisfactory photographs of the corona. These are very valuable, but it is desirable to repeat them.

If Government, then, will sanction the expense, I purpose to undertake the following work in the Total Eclipse of December 11-12 of the current year:—

With the Spectroscope.

I propose to examine the remarkable bright line which has been seen on several occasions, shortly before total phase, to lie within the apparent Moon's limb. This has, I think, never been done. I then propose to seek for, and, if possible, ascertain the conditions under which the stratum of vapour, seen by Messrs. YOUNG and PYE, but unseen by M. JANSSEN, is visible. Then to examine suitable parts of the corona (guided by experience of previous Eclipses, especially my own work in 1868), with a view to localizing, if possible, the various forms of spectrum. As the total phase ends, I would confirm the previous results. Short as is the duration of this Eclipse, I hope, by suitable arrangements, to do all this.

Photography.

If I can procure a competent assistant, I purpose endeavouring to procure Photographs of the corona; three or four can be got without any difficulty.

The spectroscopic work requires apparatus from England. I have sent home to Mr. HUGGINS a description of what seems to me to be suitable; and

I hope that, by the assistance of the telegraph, I may be able to put the work in hand, so that the apparatus may be out in time. Essentially it consists of a six-inch refractor, fitted with a spectroscope of considerable dispersion, and firmly connected with a second telescope of comparable power, to be used by a second observer as a finder. This apparatus is expensive, but the telescopes, not being only of use for the Eclipse, could be turned to other purposes.

The photographic arrangements can, I believe, be made here. I propose borrowing from the Photographic Branch of the Surveyor-General's Office a lens, which will form the main optical arrangement. The stand I propose making up, and also to purchase such portions of photographic apparatus as I can turn to account, and all the requisite chemicals. It is necessary to do this if any photography is to be done, as the telescope used in 1868 was sent to England by order of the Secretary of State. I am not sure that any expense will be incurred now beyond what would have, in any case, been necessary in providing a new stand and making necessary alterations, but there would have been a gain in efficiency.

As to Personel.

Captain Herschel, to whom the Royal Society confided their instruments for the Eclipse of 1868, has consented to share the work necessary to use the spectroscope. We both think that the plan I have proposed has advantages, apart from the one that, should one or other of us, from unforeseen circumstances, be unable to do his share, the other will, with such intelligent aid as would be procurable, be able to secure valuable results, though not, perhaps, all that we could jointly obtain. I have not heard yet that Captain Herschel's services can be spared, but hope to do so before this goes off. I have not arranged yet for a photographer, but that can easily be done if the cost of the project is sanctioned. I have included a salary in my estimate, but I hope to secure the services of an officer who could take leave.

As to Place.

I purpose to take some point on the Nilgherry Hills as my station. I hear a very high character of the weather in December, the hills being far above the clouds and mists of the north-east monsoon. The central track of the Moon's shadow passes exactly over the station of Kotagherry ; but it will be more important, I think to get the highest available point than to be precisely on the central line. Dodabetta, the site of the old meteorological

observatory, will be near enough, and will probably be chosen. So favourable an opportunity of getting rid of the lower strata of our atmosphere, as is afforded by the existence of a mountain 8,600 feet high, close to the central line, is rarely available.

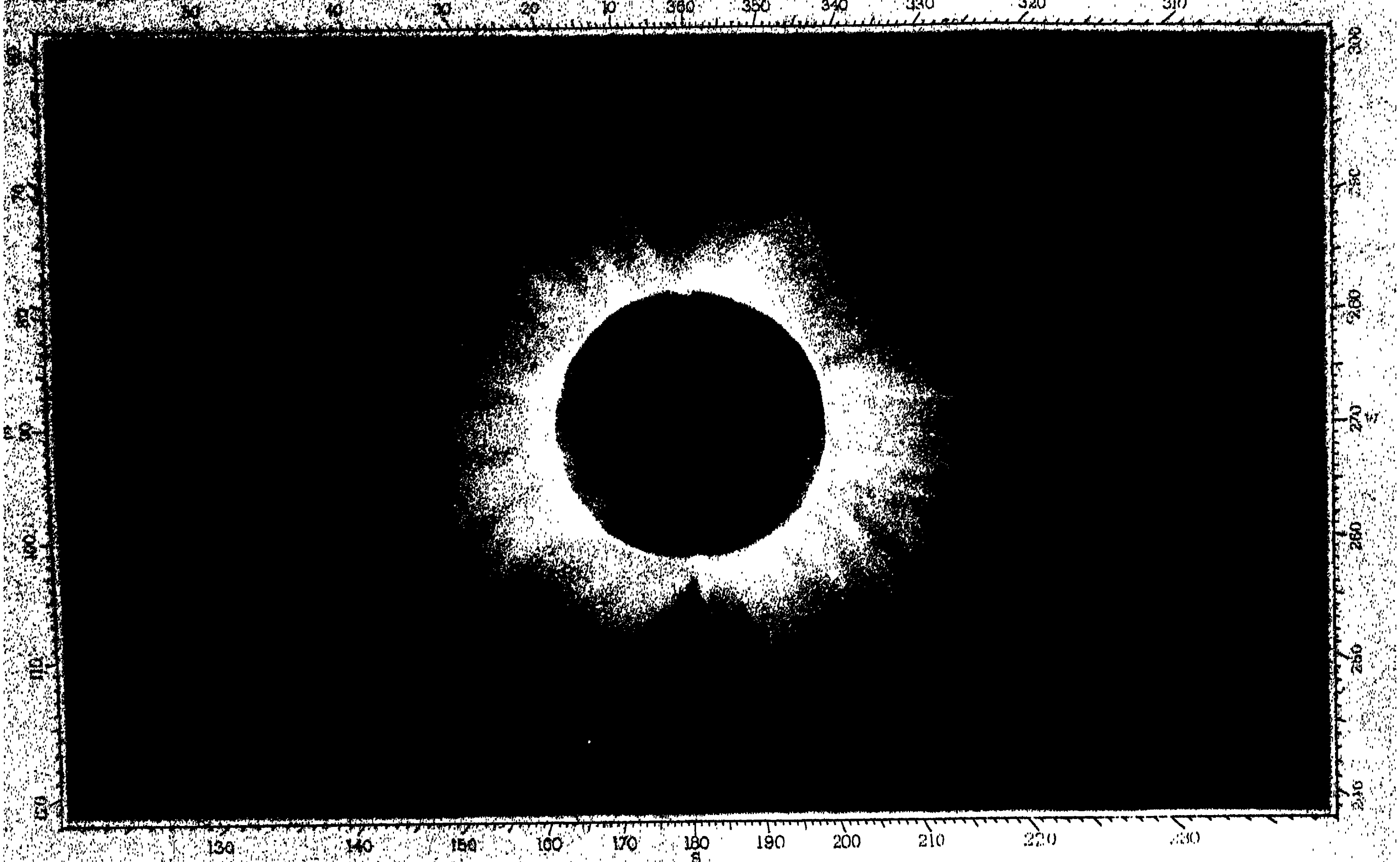
Annexed is an estimate (necessarily rough) of the probable cost of carrying out this project, in framing which I have endeavoured to err on the safe side. I have assumed that Captain HERSCHEL's pay will be defrayed from the Trigonometrical Survey, as it was in 1868.

CALCUTTA,
June 3rd, 1871.

J. F. TENNANT,
Lieut.-Col., *R.E.*

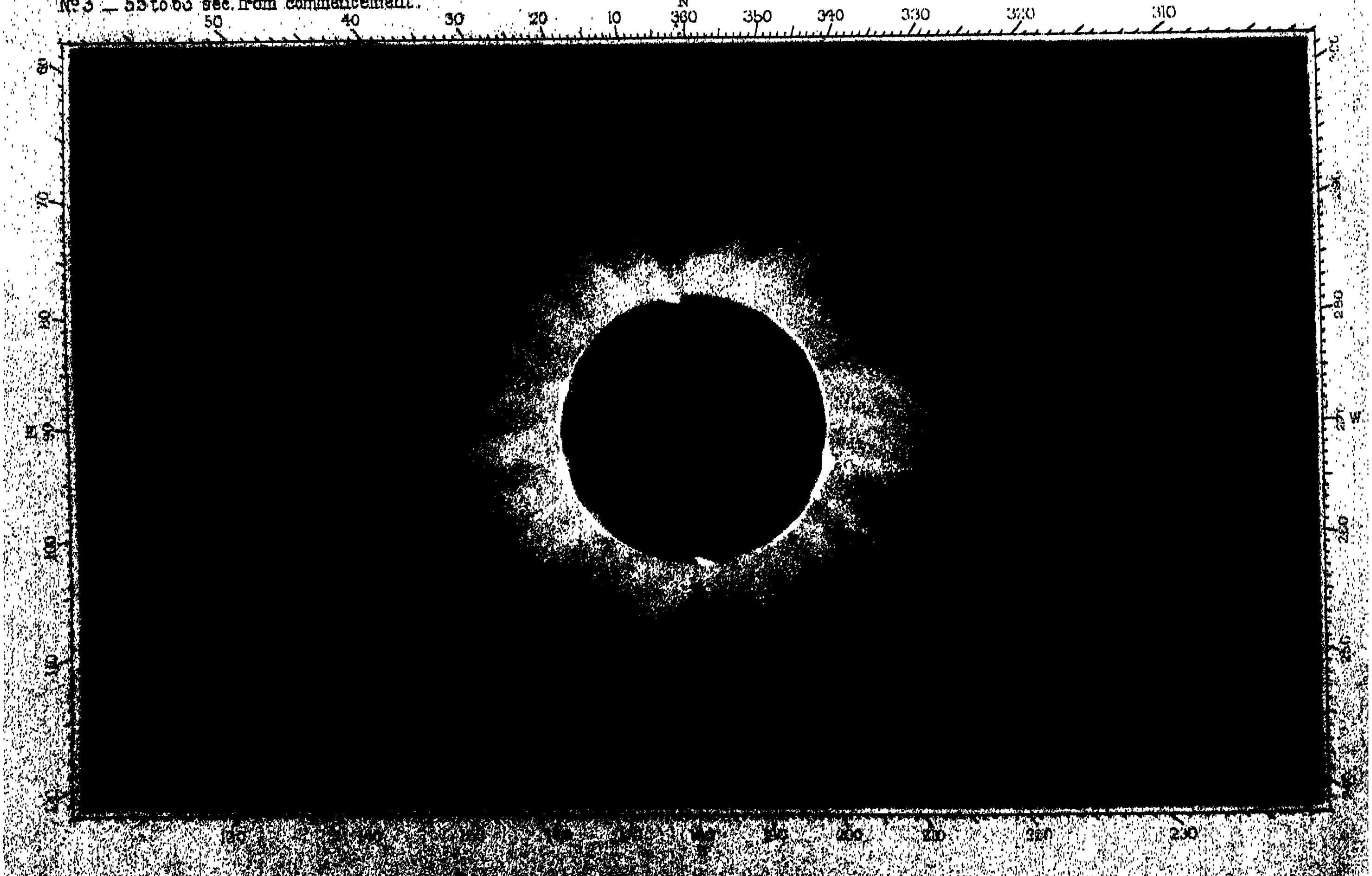
The Paper as presented to the Society was accompanied by two Photographs: (1) The double Telescope with Spectroscope, (2) the Photographic Camera; it has not been thought necessary to reproduce these. Of the six Photographs of the Eclipse, the Plates give Nos. 1, 2, 3 and 4; No. 5 was very faint, and No. 6 defective, and Mr. DE LA RUE, who (with the concurrence of the author) selected the four for engraving, thinks that they show everything that can be made of the series; Nos. 1 and 3 are placed in juxtaposition as best showing the motion of the Moon relatively to the corona.—ED.

№ 1 _ 4 to 19 sec. from commencement.

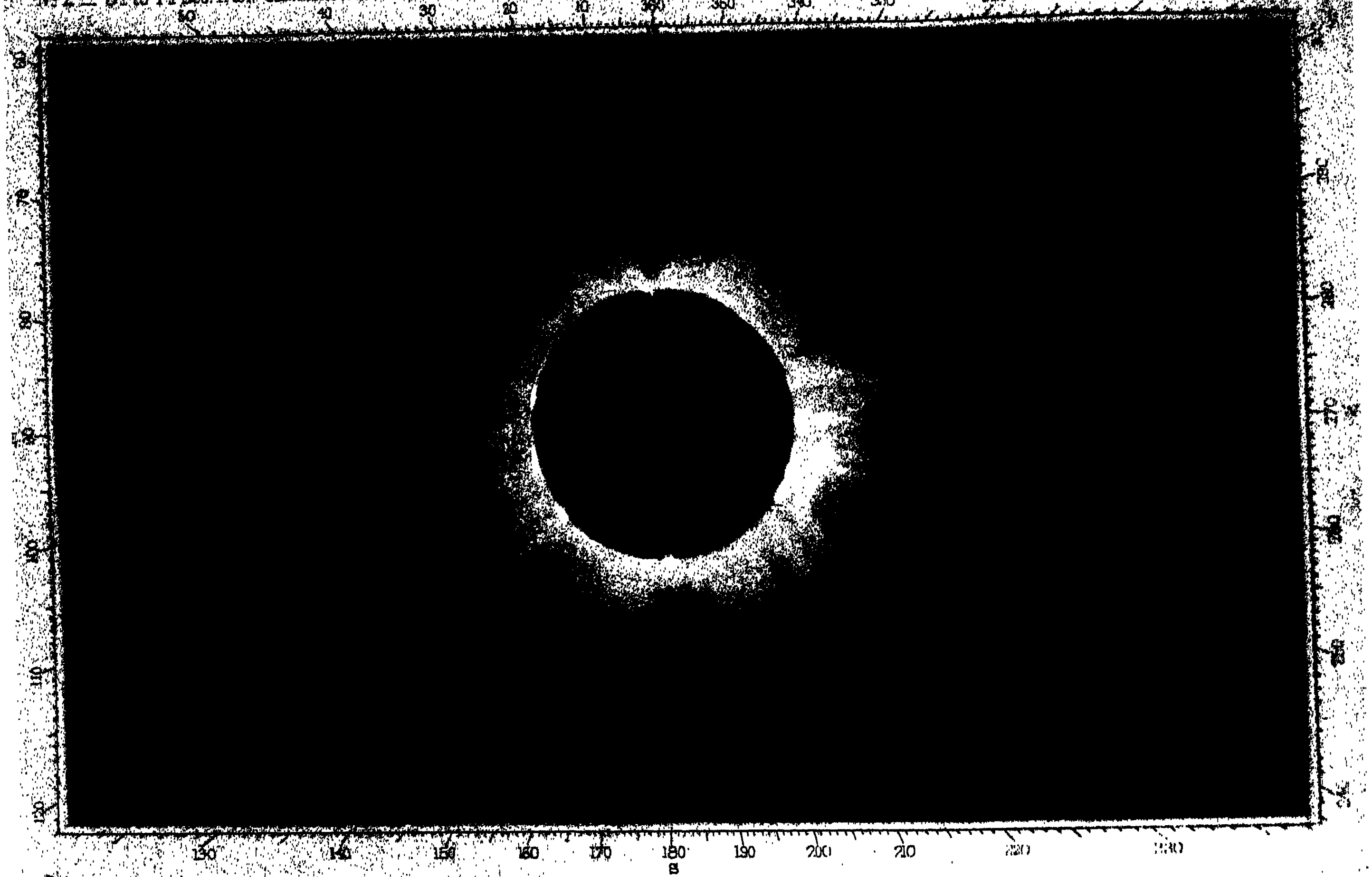


THE CORONA, DODABETTA, DEC. 11-12, 1871.

№ 3 _ 55 to 63 sec. from commencement.

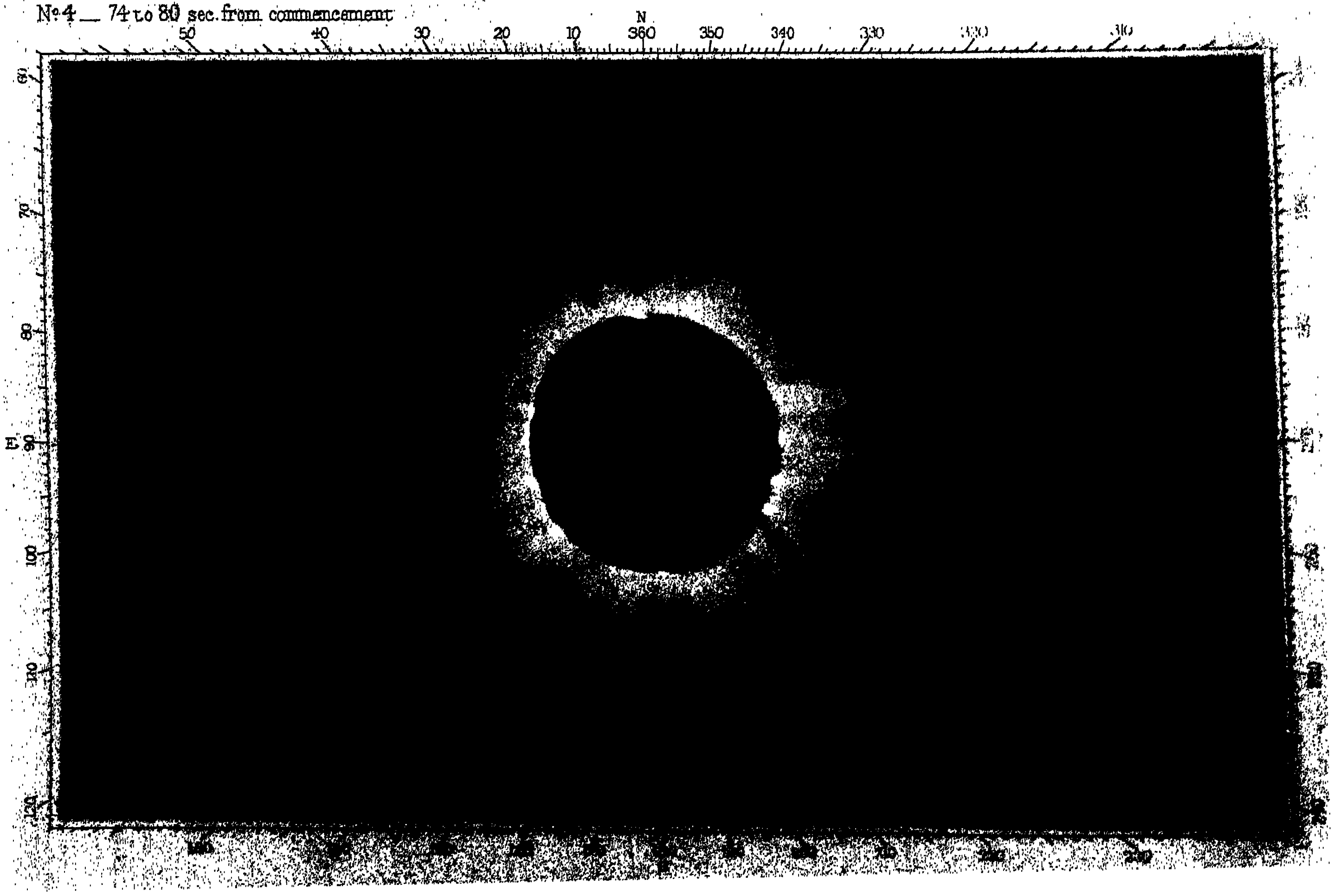


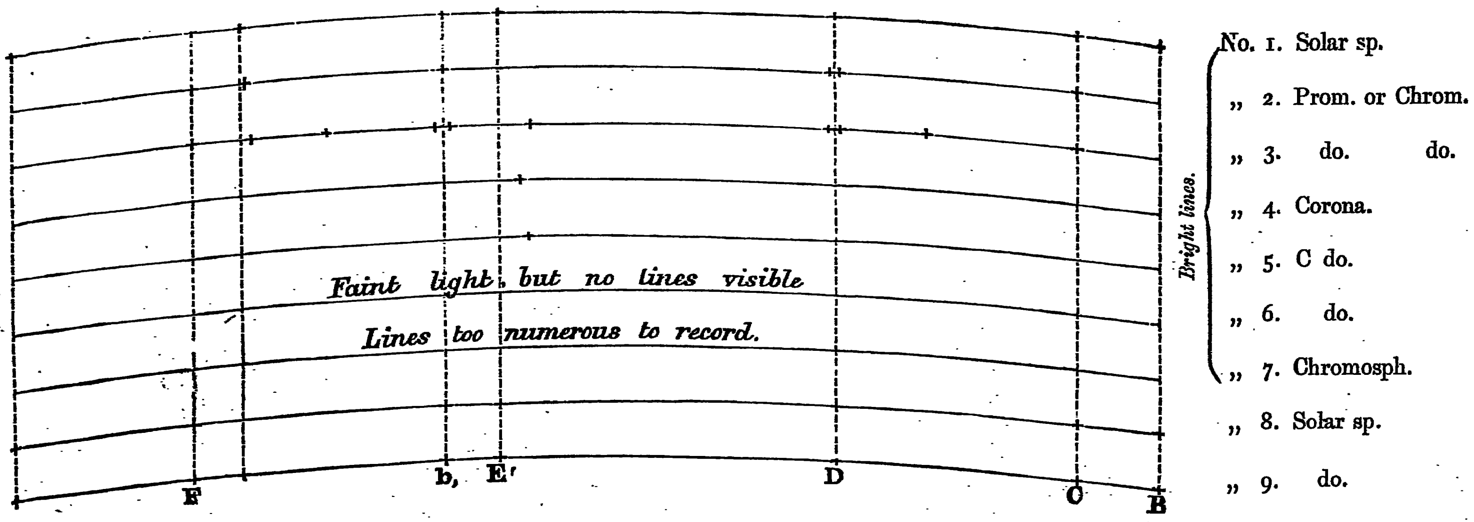
No 2 — 3½ to 14 sec. from commencement.



THE CORONA, DODABETTA, DEC. 11–12, 1871.

No 4 — 74 to 80 sec. from commencement





True copy (treble the size of original) of the record on the register card used during the Total Eclipse of December 11th 1871.

II. *The Total Eclipse of the Sun*, 1874, *April* 16. By E. J. STONE, M.A., F.R.S., Her Majesty's Astronomer, Cape of Good Hope.

ON the 16th of April 1874 there occurred an Eclipse of the Sun, which was total throughout the northern portions of the Cape Colony. The central line of totality first touched land in south latitude 29° 46′, about thirty miles south of the village of Port Nolloth. The Eclipse then swept across the continent, with a zone of totality about 180 miles in breadth. Unfortunately, however, the greatest part of the country within this zone was very sparsely populated. Considerable portions were little better than a desert; but the Diamond-fields, Bloemfontein, the capital of the Orange Free State, and some other centres of population, fell within the zone. There were also, scattered over the most remote parts of the Colony, gentlemen connected with the Civil Service, land surveyors, ministers of religion, and others, who were sufficiently interested in the occurrence of a Total Eclipse to make any observations in their power. It was only necessary to point out in what way their aid could be useful to secure their co-operation; but the instrumental means possessed by such observers were small. My own instrumental means were not altogether such as I could have desired; but an application made to the Royal Astronomical Society for the loan of instruments better fitted for the work, and for advice upon the points to which attention could be best directed in the present state of our knowledge of Solar Physics, did not meet with the response I expected, and I found myself thrown entirely upon my own resources. The problem which appeared to me to chiefly require attention was the extent and constitution of the outer corona. This was a problem

also to which the resources at our disposal could be best directed with hopes of success in the way of hand drawings of the outlines of the outer corona, at distant parts of the Colony for comparison *inter se*. To direct the attention of my fellow-colonists to the Eclipse, and to secure their co-operation in the direction indicated, a letter was addressed to His Excellency Sir H. Barkly, K.C.B. This letter was, at His Excellency's request, subsequently forwarded to the editors of the local newspapers, and generally circulated throughout the Colony. A copy of this letter is included in the present paper, to show the nature of the precautions adopted to secure accuracy in the drawings made.

"Royal Observatory.
"*March* 21*st* 1874.

"His Excellency Sir Henry Barkly, K.C.B.

"Sir,—I have the honour to forward some data respecting the Solar "Eclipse of April 16. I venture also to offer some suggestions respecting the "points to which I think the attention of observers might be directed with the "best prospects of success.

"The central line of shadow enters South Africa close to Buffel's River, "about 30 miles from Port Nolloth. The duration at this point will be about "$3^m\ 38^s$. The shadow then sweeps across the whole Colony with a breadth of "about 180 miles, and at the rate of about 50 miles a minute. At O'okiep the "first contact takes place at $2^h\ 41^m\ 16^s$, and the last contact at $5^h\ 2^m\ 27^s$. The "duration of totality is about $3^m\ 35^s$. I intend to station myself near this "point.

"The central path next sweeps across a desert track. I can only find "one station, Pella, on my map near the central line. It next passes about "50 miles north of Hope Town, and a few miles south of Pniel.

"The first contact at Pniel will be about $3^h\ 23^m\ 57^s$, the last contact at "$5^h\ 35^m\ 17^s$.

"I have assumed in these calculations 28° 30′, and $1^h\ 41^m\ 43^s$ for the "south latitude and longitude of Pniel. This is, as nearly as I can estimate, "its true position, and it is to this position that the calculations refer. The "duration of the totality at Pniel will be about $3^m\ 15^s$.

"The central line passes about 30 miles north of Bloemfontein. The first "contact at this station will be at $3^h\ 24^m\ 40^s$, and the last contact at $5^h\ 35^m\ 40^s$. "The Eclipse will be total; but the duration will not be very great. I have "not had time to compute the exact duration.

" The Eclipse will be seen as a Total Eclipse throughout Natal, but the " duration will be very short. D'Urban lies very nearly on the limiting line. " It is very doubtful whether the corona will be seen at all in the southern " parts of Natal.

" The first contact at D'Urban takes place at 3^h 50^m 46^s. The sun will " set before the end of the Eclipse.

" At Cape Town the first contact will take place at 2^h 37^m 16^s, and the " last contact at 4^h 55^m 10^s; only about a twentieth part of the Sun's disk will " remain uncovered; but the direct light of the Sun from this portion, and the " scattered light from the fully illuminated southern sky, will prevent the " corona from being seen.

" At Port Elizabeth the first contact will take place about 3^h 16^m 58^s, " and the last contact at 5^h 35^m 40^s.

" With respect to the observations which can be made without instru- " ments or with surveying instruments:—

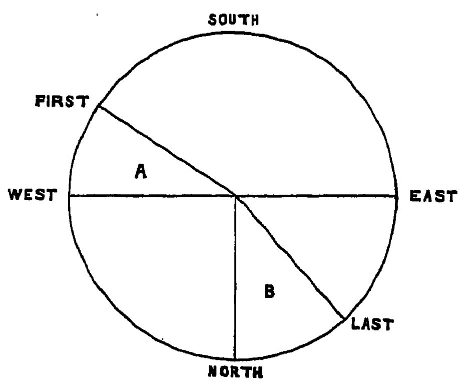
" (*a*) All accurate determinations of the first and last contacts will be " valuable in fixing the longitudes of the observers. I shall be prepared to " work up for the determination of longitude any observations of the first and " last contacts which may be sent to me with materials for testing the accuracy " with which the local times and latitudes have been determined.

" (*b*) Along the central line of totality the corona is certain to be well " seen, unless, of course, the view should be shut off by clouds. The red " prominences seen near the Moon's disk are known to consist of masses of " incandescent hydrogen, and belong to the Sun. The corona proper has ' also been proved to be a solar appendage; but beyond this, comparatively " speaking, bright corona there appears a much fainter mass of luminous " matter of vast extent and generally of a most irregular form. It is some- " times assumed that this is also a solar appendage; but the point cannot be " regarded as settled, and it is to this point that I would chiefly direct " attention. If these outlying portions of the corona belong to the Sun, they " may be expected to remain sensibly unaltered by the mere shift of the " observer's station, within the limits at our disposal; but such need not be " the case if the appearances presented to us arise from modifications of " the light of the corona proper by the Earth's atmosphere. Drawings " of these appearances, taken at different stations, should therefore " enable us to settle the point raised. Unfortunately the drawings which " have been previously made have been distrusted.

" It would be useless to multiply inaccurate drawings; but I think that,

" with some care, inaccuracy such as affects the scientific value of drawings " might easily be avoided. Let anyone who shall have the good fortune to " be near the central line on the day of the Eclipse, draw a circle on paper or " cardboard; divide this circle into twelve equal sectors of 30° each by " lines produced to about three or four times the diameter of the circle. Let " a weight be suspended by a string to mark the vertical plane between " the observer and the Sun. Let the paper or cardboard be placed on a con- " venient stand, with one of the prolonged lines in the vertical plane of the " string, and this diameter marked top and bottom. As soon as the totality " has begun the observer should rapidly fill in the outline of the outlying " portions of the corona, care being taken to draw it as nearly as possible on " the same scale to the circle as the corona bears to the Moon's disk; but the " most important point of all will be to put all the prominently marked branches " of the outlying corona into the proper angles, as marked by the straight " lines through the centre of the circle produced. I would recommend that " attention should be confined almost entirely to these outlying portions; " and that, instead of trying to make two drawings in the 3^m available, an " examination of the drawing should be made as soon as it is finished, and " notes made of any discrepancies observed. The original drawings should " remain untouched. If these drawings be made in the manner indicated, by " several persons at different parts of the Colony, I think it most probable " that the question raised may be settled. I should be happy to receive such " drawings, and to forward them to the Royal Astronomical Society.

" The following gives approximately the angles at which the first and " last contacts take place, as measured on the Sun's disk and seen without " inversion.



	A.	B.
	°	°
Observatory . .	27	58
O'okiep . . .	29	62
Pniel	30	64
Port Elizabeth . .	25	59
Bloemfontein . .	27	63
D'Urban . . .	29	

" I have &c.,

" E. J. Stone."

The times given in this letter are only approximations. Subsequently, a short note was added, which gave the positions of the points of the first and last contacts referred to horizontal and vertical lines of reference at the different stations, as more generally useful than the positions referred to the equator.

The central line of totality was rendered accessible from Cape Town by two steamers engaged in bringing copper from the Namaqua mines for transhipment to England. I determined, therefore, to place myself near the central line in Namaqualand. As no provision whatever had been made to cover the necessary expenses, and I was most reluctant to stop more than was absolutely necessary the Observatory work, I determined, after much consideration, to take no assistant with me, and to confine my attention during the totality chiefly, if not entirely, to a spectroscopic examination of the outer corona. My instrumental means were as follow :—A four-inch telescope, mounted on a tripod stand, with horizontal and vertical motions, and provided with a small finder telescope. The whole instrument and stand could be conveniently packed for safe carriage. This telescope was most kindly lent to me by Henry Solomon, Esq., of Cape Town, to whom my thanks are greatly due. My spectroscope was a star spectroscope made for me by Mr. Browning, but it has now two dense flint prisms of 60°, instead of the two of 35° which it originally had. With the spectroscope in its present state I can see the spectrum of a prominence without an eclipse. The dispersion of two prisms of 60° was abundantly sufficient for the chief object I proposed to myself; but I missed a spectroscope with readier means of measuring the positions of the lines seen, an equatoreal mounting, and perhaps a driving clock, and I could have wished for a telescope of larger aperture. Some difficulty was experienced in obtaining a firm connection between the telescope and spectroscope. I ultimately adopted the plan of wrapping a wash-leather around the spectroscope tube, and thus making it fit the tube of the telescope. In this way a very firm attachment was secured, but the spectroscope could not be quickly adjusted, and the telescope was not available for time determinations. This, however, was not important. In the small telescope of the spectroscope I placed two wires, one for micrometrical measures, the other for eye estimations. My intention was to leave the instrument untouched after the bisection with the micrometer wire of the line whose position was required, until the reappearance of Fraunhofer's lines. The position of only one line could be thus accurately fixed, but the positions of any other lines could be filled in by estimations referred to the distance of the two micrometer wires apart. My wife undertook to keep the part of the Sun or corona to be examined within

the slit, and after some little practice I found that she could do this, by the aid of the finder, with perfect certainty, and she performed this part of the work on the day of the Eclipse. Besides the instruments for the observations of the Eclipse, I took with me to Namaqualand a complete set of magnetical instruments, and secured determinations of the magnetical elements at four stations. The whole of the instruments were carefully packed, and arranged so that they could, when necessary, be carried with the observer in a cart. I started from Cape Town by the U. S. C. Steamer "Namaqua," Captain Barker, on Tuesday, April 7, and arrived at Port Nolloth on Thursday, April 9. I returned to Port Nolloth on the evening of Wednesday, April 29, but from bad weather the steamer could not pass the bar, and I was detained there until May 6. I reached the Observatory on May 9. Port Nolloth was near the central line, but it was quite unfit for an observing station, on account of the prevalence, during the winter months, of a dense mist. This mist extends generally about 15 miles inland, beyond which limit it scarcely ever reaches. My original intention was to place myself on the central line near O'okiep, but R. T. Hall, Esq., C.E., the engineer in charge of the Cape Copper Company's Works, strongly urged me to take my station near Klipfontein, a station about 55 miles from the sea. The advantages urged were, that a tramway extended a little beyond Klipfontein, to Steinkop, and that the instruments could be carried thus far without danger. The journey from Steinkop to O'okiep could only be made by cart, and the road was represented as an exceedingly rough one for the safe carriage of delicate instruments, however carefully packed. Mr. Hall also offered, with considerate kindness, to receive us at his cottage at Klipfontein, and to make such arrangements that my time should be unfettered for the work which I required to do. After a careful consideration of the position of Klipfontein, and finding that it was less than 20 miles north of the central line, I determined to accept Mr. Hall's advice and kind invitation. The magnetical observations at Port Nolloth were completed on April 12, and the instruments repacked. The following morning we started for Klipfontein, and arrived at the cottage in the evening. Tuesday and Wednesday were spent in completing a set of magnetical observations, and preparing for the Eclipse. The station selected was, as determined by Mr. Hall, 3,000 feet above the sea level. Its approximate latitude and longitude are 29° 14′ south, $1^h\ 10^m\ 40^s$ east. This longitude results from the observations of contact with the small theodolite. The view is perfectly uninterrupted on every side, and the air clear to an extent which it would be difficult for one

not accustomed to the dry atmosphere of the interior of such a continent as Africa to realise. Rain but very seldom falls at Klipfontein ; but, curiously enough, a few ominous clouds did collect on the distant mountain-tops on the evening before the Eclipse, and gave rise to some little anxiety. The day of the Eclipse was, however, perfectly free from cloud, and no finer one could have been desired for the observations. The following were the arrangements made for the observation of the Eclipse at Klipfontein: Mr. Hall undertook to record the changes of temperature during the Eclipse. Mr. Henry Hall, C.E., undertook to make an outline drawing of the corona. Mr. H. Hall's experience as a mechanical draughtsman was a guarantee of the accuracy with which such an outline drawing would be made. Miss Alice Hall, a young lady accustomed to sketching from nature, most kindly undertook to make a second outline drawing of the corona. My wife undertook to feed the spectroscope, by the aid of the finder, with the parts of the corona which I wished to examine. My work was confined almost entirely to the spectroscope. I determined beforehand to very strictly limit myself to the work which I would attempt. The following are the points which I determined to examine: —

1st. During the Partial Eclipse: the existence or non-existence of additional absorption lines in the spectrum near the Moon's limb.

2nd. At the commencement of the totality : the existence or non-existence of the general reversion of Fraunhofer's lines in the corona at the border of the photosphere. Some doubts appeared to have been thrown upon Young's observation of this reversion by the Indian observations of 1871, Mr. Lockyer, amongst others, having looked for and failed to notice anything of the kind.

3rd. An examination of the outer corona, with especial reference to its extent, and the way in which any bright-line spectrum seen might vanish as the spectroscope was swept farther from the Sun's centre.

4th. An examination of the corona for the presence of Fraunhofer's lines. The evidence, so far as I knew, was entirely against the presence of these lines in the spectrum of the corona. I have already stated that the telescope employed had a clear aperture of four inches ; the spectroscope, a dispersion of two flint prisms of 60°. The slit of the spectroscope was set as wide as would allow of a perfectly distinct view of the Fraunhofer lines. The finder was most carefully adjusted, so that a spot of light upon the cross wires was in the middle of the slit of the spectroscope. Before attempting to give the results of the observations, it appears desirable to explain the

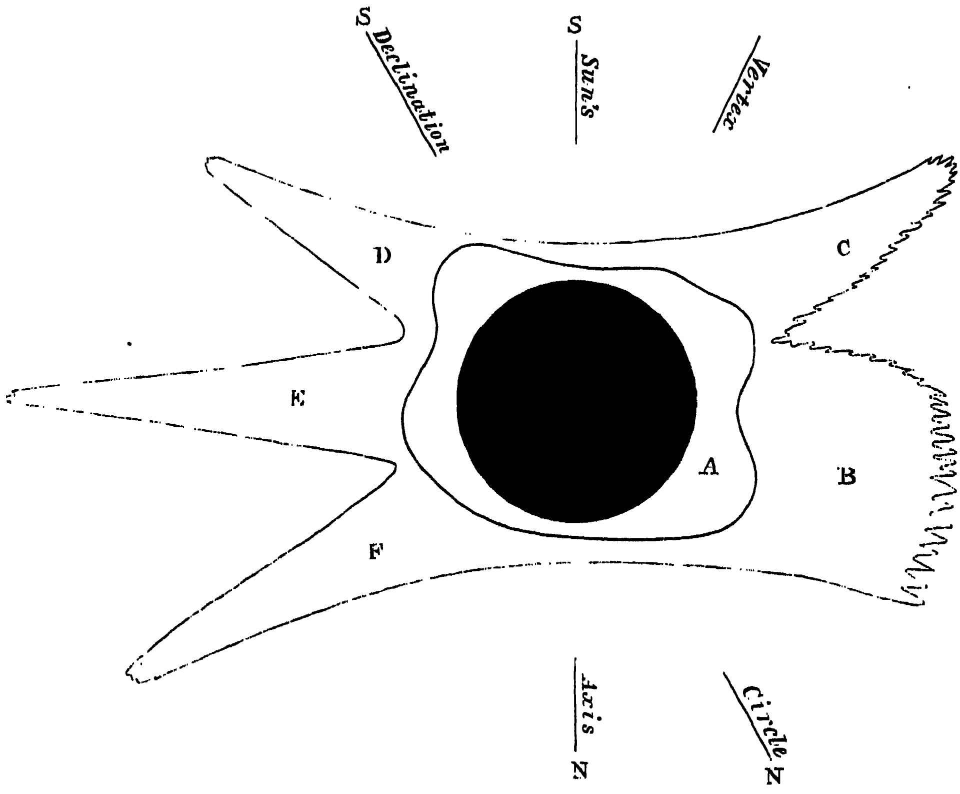
meaning of certain terms which will be used in describing the results. At the time of, and for some time after the Eclipse, I was inclined to follow what I believed to be the leading of authority, and to use the word "chromosphere" to include all that part of the corona which had been proved to be a solar appendage by the combined evidence afforded by a comparison of photographs and the existence of a bright-line spectrum. The fainter portions beyond this I called the corona proper, or sometimes the corona. But it appears to me that the word chromosphere will lead to serious confusion in our attempts to describe solar phenomena, unless its accepted meaning be more strictly defined than has, so far as I am aware, yet been the case. When the term was originally introduced, on the authority of Mr. LOCKYER, it appears to have been restricted to the envelope, consisting chiefly of incandescent hydrogen, of which the rose-coloured prominences and their bed seen at eclipses was a section. A new name was thus introduced to indicate a distinct thing. But as spectroscopic researches were extended, and it was found that other strata nearer the photosphere could, with sufficient instrumental means, have their spectra examined, and that they also gave bright-line spectra, the word chromosphere was extended to include these strata also. Nor was this all. The word has been even extended to include all the bright-line-giving corona. From the observations made this year, such a definition would include the whole of the corona seen in a clear atmosphere, and extending to some millions of miles from the Sun's centre. To accept such a definition would be to make the word chromosphere co-extensive with the word corona. I cannot think this desirable. Instead of a distinct word to define a distinct thing, we appear now to have a word to which in every description of solar phenomena something has to be ascribed, and that without any clearly defined leading idea. I shall not, therefore, in the present paper, employ the word chromosphere to explain the parts of the corona observed, but shall restrict myself to the use of the words inner and outer corona. The distinction between these was strongly marked to the naked eye, and in the small finder in the Eclipse of last April. For clearness of explanation of the parts of the corona examined with the spectroscope, I shall refer to a composite drawing formed from those made at Klipfontein.

First with respect to the existence of additional absorption lines in the Sun's spectrum near the Moon's limb. I examined this point with considerable care during the partial phase, but I could not detect the presence of any additional lines, nor any sensible change in the appearance of any of the FRAUNHOFER lines in the spectrum near the Moon's limb from that presented at considerable distances from it. I consider that these observations afford

another proof that there does not exist any sensible atmosphere around the Moon, and that we are warranted in assuming that no sensible refraction of the rays of light from the Sun or corona can take place at the Moon, and that no modification of the visible corona can be attributed to any such cause.

As the time of totality approached I rested my eye for some time. The diminishing segment of the Sun's disk was then brought into the centre of the slit, and carefully kept there until the instant of totality. At that

COMPOSITE DRAWING.



instant, and for some little time afterwards, the field appeared to be full of bright lines of very different lengths. My impression was that all the Fraunhofer lines were seen reversed, but this is, of course, only an impression. I can only state as a matter of fact that a very large number indeed of bright lines were seen. I had hardly recovered from the surprise at the sight presented, and begun to attempt to count the lines, when the greatest portion of them vanished, and I saw little more than a hydrogen spectrum.

It is difficult for me to form any correct idea of the time during which the general reversion, or what I assumed to be the general reversion, of the Fraunhofer lines lasted; but I should hardly consider that it could have been longer than a second. From the shortness of many of the lines it would have been quite impossible to have seen their reversion unless the slit had been very perfectly adjusted parallel to the tangent to the Sun's limb at the point of last appearance of the Sun. Not caring to spend my time upon the spectrum of the prominences, I looked up at the Eclipse to see whether the brightness of the outer corona appeared sufficient for the work which I intended to do. This was the only opportunity I had of seeing the Eclipse during the totality, except through the spectroscope. The sight was grand and impressive beyond description. Several stars were seen, and *Venus* was a most conspicuous object near the corona. My first impression was that the corona consisted entirely of a pink-coloured irregular ring. The rose-coloured prominences were seen clearly, and were to me of a much deeper red than the inner corona. When looking carefully for the parts beyond this inner corona (or, as I at the time regarded it, the chromosphere) I saw most distinctly and without any difficulty when attention was fixed upon it, the branches of the outer corona marked C and B in the composite picture. I believe that the drawing of these portions of the corona by Miss Alice Hall is correct, except that in her drawing the edge of B is divided into something like four brushes. The outline appeared to me much more irregular than this, and Miss Hall, directly after the Eclipse, expressed an opinion to much the same effect, viz. that there was too much detail in this part to be accurately drawn in the time, $3^{m}\ 20^{s}$, available. I feel certain that the visible extent of branch B has been under- rather than over-extended in Miss Hall's drawing. The outer corona appeared to me quite sufficiently bright for the examination which I intended to make; I therefore asked my wife to sweep the telescope quite away from the inner corona, out into the middle of the branch B, and to keep it directed to that part of the corona until I gave further instructions. This was done. On sweeping across the inner corona the hydrogen lines were seen extended across the slit; a line somewhere in the green, and two or more much fainter lines of less refrangibility than the green line, were also seen. There was also a pretty bright spectrum which appeared continuous; but the spectroscope was swept rather rapidly over the inner corona, and I do not feel myself in a position to speak with any great certainty of its spectrum. When the telescope had been fairly directed to the middle of the branch B the spectrum was carefully examined.

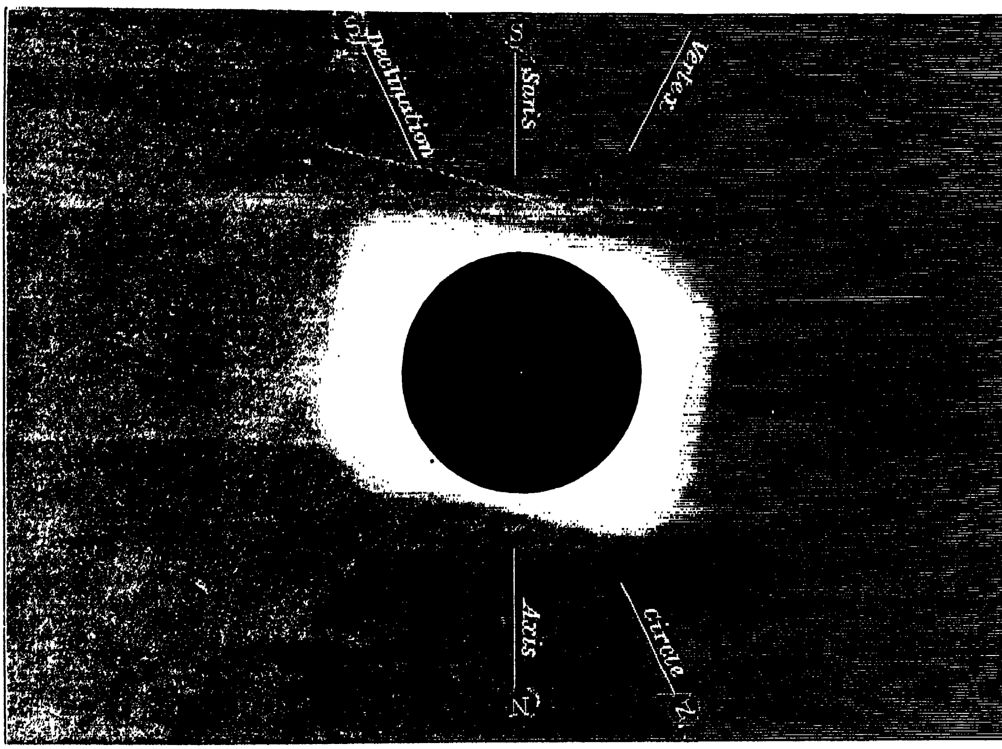
I could, in the spectrum of this part of the corona, only distinguish one bright line. If there were any other bright lines present they were so much fainter than the line referred to that I could not, after a careful examination, see them. But besides the one bright line there were certainly dark or absorption lines present in the spectrum, although they were seen with great difficulty. I next asked to have the telescope slowly moved towards the extreme visible limit of the branch B, and requested that this should be continued until I stated that I had lost the bright-line spectrum. This was done. This line, which extended across the slit, gradually became fainter, until I lost sight of it from extreme faintness. At that time my wife states that the extreme visible limit of the branch B had been reached (judged from its position on the cross wire of the finder), and that the Moon's limb, but not all of the inner corona, was out of the field of the finder. The field of view of the finder is very nearly three diameters of the Sun, and the part of the corona under examination when the line-spectrum was last seen must therefore have been more than a degree from the Sun's centre. This examination having been completed, the telescope was again directed to somewhere about the middle of the branch B. The small telescope of the spectroscope was unclamped and the spectrum examined from end to end with the greatest care, but I could not perceive any other bright line than the one seen before. The telescope of the spectroscope was then clamped and a careful bisection made with the micrometer-wire. The telescope was then left untouched; but another examination for the presence of absorption lines was made, with the same result as before. I felt convinced of their presence, but they were very faint and seen with great difficulty. As soon as the totality was over the micrometer was read and a bisection of the line E and the nearest of the *b* lines made to prevent any possibility of mistake. The bright line turned out to be line 1474 of Kirchhoff's scale. The wave-length from my observations was 5,312, which appears to differ about the breadth of the D lines apart from the value determined for the line seen in the spectrum of the corona by Young. I was not certain, however, that the line measured by Young belonged to the outer corona. The inner corona extends in some directions to ten or eleven minutes from the Sun's limbs. At one of the most important of the Indian stations at the Eclipse of 1871 it is reported that there was no visible spectrum of the corona at five minutes from the Sun's limb. The difference, however, between the wave-length of the line examined by me and that examined by Young is smaller than I could answer for with my dispersion; and I have no doubt *now* of the identity

of the wave-lengths of the lines seen ; but I should have been most reluctant to have assumed this without proof. My observations refer to the outer corona, and I knew and know of no grounds upon which the identity of the inner and outer corona could have been assumed. I therefore regarded and regard the determination of the wave-length of the line seen as important. My spectroscopic examination of the corona was almost entirely confined to the outer portions. I cannot therefore speak with confidence of the spectrum of the inner corona. My plan was to confine my attention to the outer corona, and to this plan I adhered. I do not regret the restrictions thus imposed upon myself: and, should I ever have the good fortune to see another total solar eclipse, I would restrict myself in like manner to one or two points which I deemed important, although of course not necessarily the same as those to which I confined my attention in 1874. All I can say with respect to the spectrum of the inner corona amounts to this, that I saw the hydrogen spectrum over a considerable portion of it, with the lines the full length of the width of the slit ; that I saw a bright line which I have every reason to believe to be the same as that seen in the spectrum of the outer corona, and two — I believe three — fainter lines of less refrangibility, and a spectrum which appeared to me continuous, but rich in red light. I believe that the FRAUNHOFER lines were not visible in the spectrum of this part of the corona, but my examination was, as I have stated, too imperfect to allow me to express any confident opinion upon the point. In the spectrum of the outer corona I feel certain that the FRAUNHOFER lines were present. No attempt was made to observe the general reversion of the FRAUNHOFER lines at the end of the totality.

I now come to the outline drawings of the corona made at Klipfontein ; approximate latitude and longitude 29° 14′ south, $1^h\ 10^m\ 40^s$ east. The drawings marked γ and δ were made respectively by Mr. HENRY HALL, C.E., and Miss ALICE HALL, who were seated side by side at the same table. The drawings were made on prepared paper divided into sectors of 30° and, for estimations of distances, into circles with radii two and three times the radius of the inner circle. The direction of the vertical plane was carefully determined in accordance with the general instructions of my letter. But, notwithstanding the precautions taken, I was astonished to find, when, after the termination of the totality, I looked at the drawings, that there was not a trace of any similarity between them. Mr. HENRY HALL's outline did not extend to quite 11′ from the Moon's limb. Miss ALICE HALL's extended to 1° 40′ from the Moon's limb in one direction, and to very large angular distances in

other directions. I had myself examined with the spectroscope the corona to a distance from the Moon's limb more than five times as great as the corona represented in Mr. Henry Hall's drawing. I was able to speak of the general accuracy of Miss Alice Hall's drawing of the branches marked B and C in the composite drawing, and my wife, who had seen the Eclipse well through the finder, expressed her agreement also with the general accuracy of Miss Hall's drawing. But Mr. Henry Hall's skill and practice as a mechanical draughts-

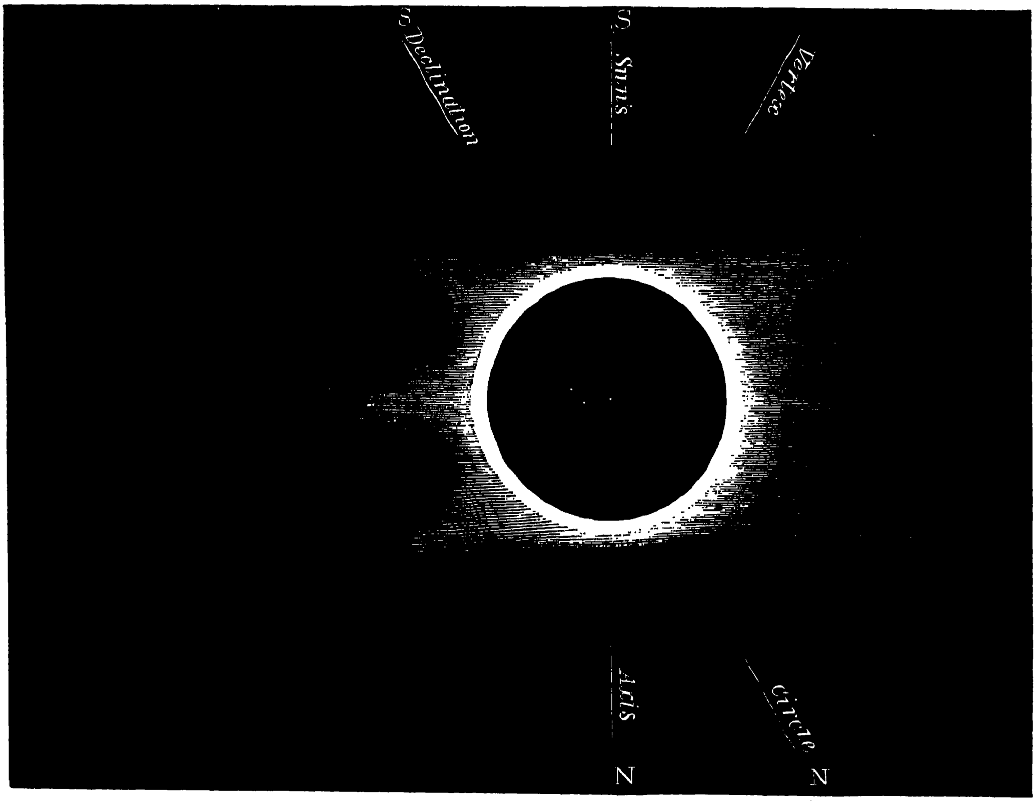
MR. H. HALL'S DRAWING. γ.



man entitled his drawing to be received with every confidence, and he was perfectly satisfied with the drawing made. If the apparent discrepancy between these drawings could be explained, the explanation would probably throw much light upon the apparent discrepancies between drawings made at previous Eclipses, which had been taken to indicate such changes in the outer corona, that, if their reality could be accepted, the optical character of this part of the corona would be established. The short eye-view which I took of the Eclipse affords, I believe, a key to the true explanation. The inner corona,

which at the time of the Eclipse I was prepared to call the chromosphere, was so much brighter than the outer corona, or, as I at the time considered it, the corona, that it required some effort to transfer the attention from the inner to the outer corona. The outer corona was, however, bright enough to be well seen when once it had attracted the observer's attention. As a matter of fact, when I looked at the Eclipse to judge of the brightness of the outer corona, I saw most clearly and distinctly, and can recall the general

MISS ALICE HALL'S DRAWING. ?.



form, and estimate with some accuracy the visible extent of the branches marked B and C of the composite drawing; but if ever I saw, I have no recollection of the branches marked D, E, and F, and if I had been asked to make a drawing of the Eclipse, I should, trusting entirely to my own impressions, have drawn something like the composite drawing, when deprived of its branches D, E, and F. Had I, therefore, returned to eye observations towards the end of the totality, and seen the branches D, E, and

F, I should have inferred that enormous changes in the form of the outer corona had taken place between the two views. I have no doubt in my own mind that a similar explanation lies at the root of at least many of those apparent changes of the outer corona which have been previously suspected to have taken place when the sky was free from clouds. Returning to Mr. HENRY HALL's drawing of the inner corona, it may be remarked that it is simply an outline drawing, and that no attempt was made to represent the character of the boundary. It will be seen that it extends to rather less than 11′ as its extreme boundary from the Moon's limb. This is, I believe, about the extent of the corona which has been obtained, well defined, in the best photographs. It will also be noticed, from a reference to the composite drawing, in which the inner corona is a tracing from Mr. HENRY HALL's drawing, and the direction of the Moon's path is laid down, that the inner corona is very much contracted in a direction perpendicular to the plane of the ecliptic, or in the direction nearly of the Sun's axis of rotation. This is also shown in the photographs of the corona made in 1869 and 1871, and will probably be regarded both as a proof of the general accuracy of Mr. HENRY HALL's outline, and of a general law in connection with the inner corona. With respect to Miss ALICE HALL's drawings, ϵ is the original, δ is a copy embodying the changes which she would have wished to introduce into the original after the examination and comparison made towards the end of totality. The shading is intended simply to represent that the light of the corona faded away by insensible degrees as the distance from the Sun's centre increased. No attempt was made to outline the inner corona. It will be remarked that the branch D of the composite drawing is marked *doubtful* in the original, and the same word is used beyond the extreme boundary of the branch B. The explanation of these remarks, made to me immediately after the Eclipse, was, that the branch D was seen, but it was very faint, and that its length appeared exaggerated and the outline doubtful, and that with respect to the branch B, the amount of detail was so great, and the edge so irregular that there was no time to draw the outline correctly. An examination of the original drawing ϵ shows that the re-examination of the extraordinary rays E and F merely verified the first impressions. They are each marked towards their extreme points as *sure*. It will be seen afterwards, when a comparison is instituted between the Klipfontein drawing and others, that these remarks are important, especially the one with reference to the faintness and doubtfulness of the branch D. I need hardly say that the original has not been touched, nor any

notes added after the end of the totality, nor by anyone except Miss Alice Hall. The existence of the faint branch D was verified by my wife.

The drawings marked α and β were made by Henry Edward Richard Bright, Esq., of the Government Agent's Office, British Basutoland. The distinction between the drawings α and β and the methods followed to secure accuracy, are explained in the following extract from Mr. Bright's covering letter:—

"Basutoland, Maseru,
"20*th April* 1874.
"(*Governor's Agent's Office.*)

"Dear Sir,—Enclosed I beg to forward the *original* sketch (marked α) "made by me of the apparent outline of the 'corona,' which sketch was "executed under considerable difficulties, as the duration of the totality here "was altogether only $2^m\ 31^s$; and never having witnessed a Total Eclipse of "the Sun before, I was quite unacquainted with the appearance of the "phenomena to be observed, and somewhat unprepared for the degree of "darkness which prevailed during the time of totality. Such, however, as "this original sketch is, I send it you in the hope that it may not be "altogether useless. It has at least the merit of being quite untouched since "first drawn, and is therefore free from corrections.

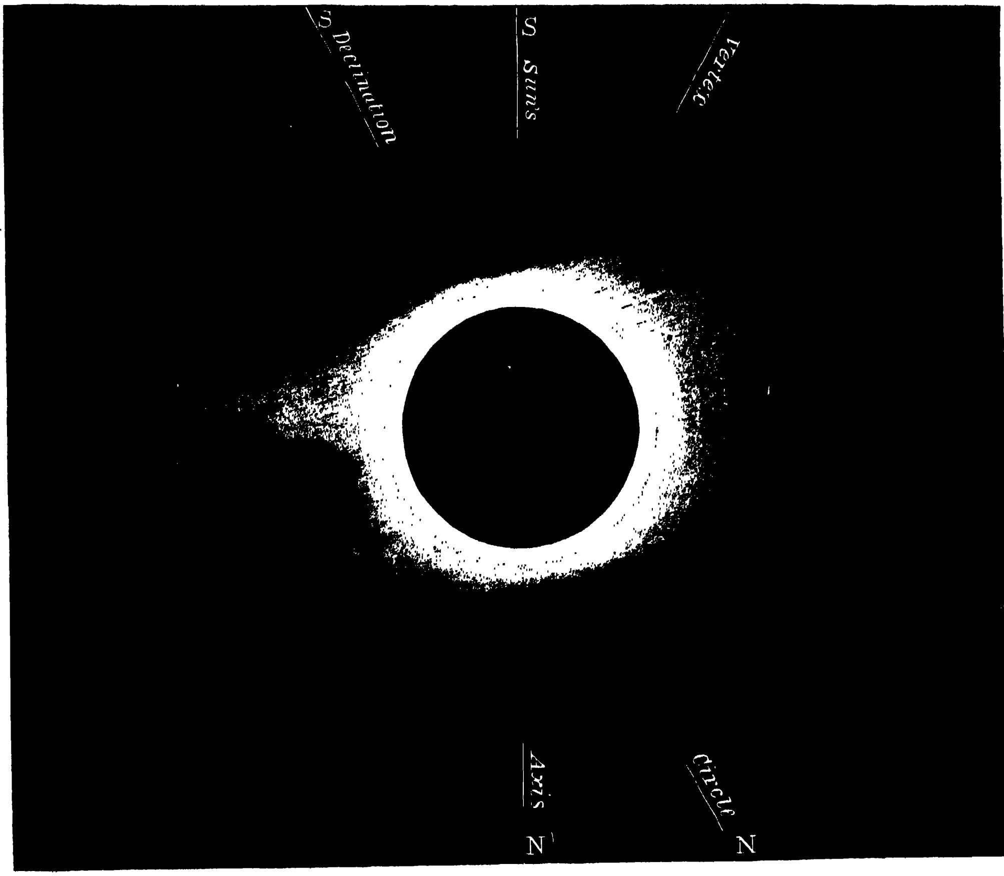
"At the same time, I enclose another sketch (marked β), which has "been made by me *since* the original (α) was taken, and which (β) I consider "represents *exactly* the outline of the 'corona' as it ought to have been laid "down at first in sketch α, had not the hurry and peculiar circumstances "under which that sketch was taken caused those errors to creep in which "will be noticed on a comparison of the two sketches, α and β, *inter se*. "Great attention was paid to the endeavour to represent, in these sketches, "the proportional lengths of the rays of the 'corona' to the diameter of the "darkened disk of the Moon, as directed in your published letter addressed "to His Excellency the Governor, Sir Henry Barkly, dated the 21st ultimo, "and subsequently published in the columns of the *Cape Argus* news-"paper.

"E. J. Stone, Esq.,
"Astronomer Royal,
"Royal Observatory,
"Cape Town."

"I remain, Dear Sir,
"Faithfully yours,
"H. E. Richard Bright.

I need hardly express the great gratification with which I found, on my return from Namaqualand, these drawings of Mr. Bright, executed with all the precautions to ensure accuracy which could have been desired, and very nearly on the same scale as the Namaqualand drawings. Mr. Bright had not the instrumental means to determine the position of his station with any accuracy, and its real position is not known. It is, however, roughly, in

MR. BRIGHT'S DRAWING. β.



south latitude 29° 25′ and east longitude from Greenwich about 27° 50′. The distance between the Namaqualand and Basutoland stations must have been more than 500 miles, and the interval in absolute time between the drawings more than 10^{m}. And yet a careful comparison between these drawings will, I think, convince anyone that the outer corona, as seen in Namaqualand and in Basutoland, were substantially identical. Referring

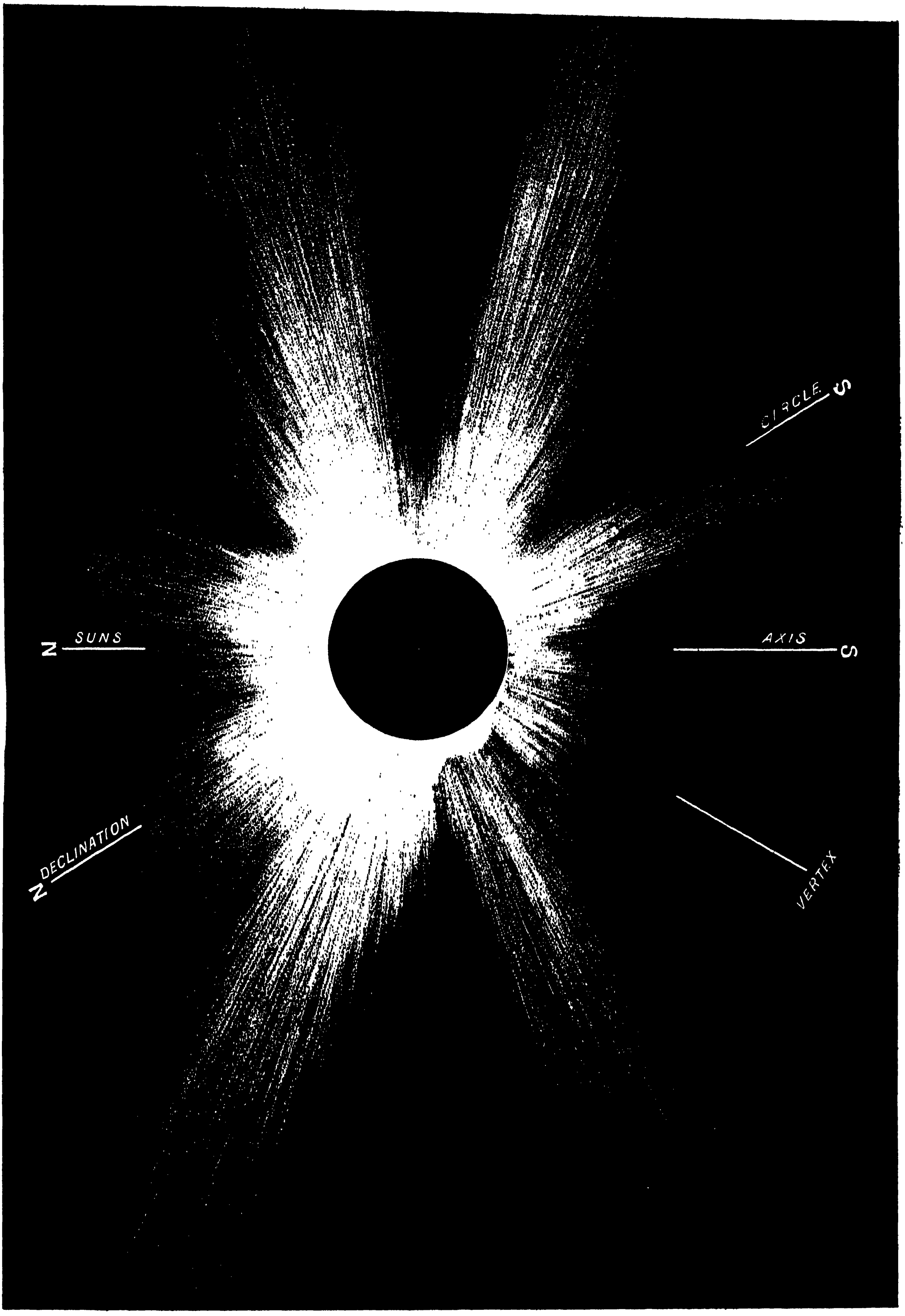
to the composite drawing for the lettering of the branches, we see that the branch C agrees, in position and in extent, very closely with that in the Namaqualand drawing. The irregular outline of the branch B is common to the two drawings. The long branch F agrees in magnitude and position in both drawings. The position of the long branch E agrees very closely in the two drawings; and although this branch is longer in proportion to the Moon's diameter in the Namaqualand drawing, this difference is not very great, and is easily accounted for by the faintness of the light as we proceed farther from the Sun's centre. The only marked difference between the Basutoland and Namaqualand drawings is the branch D. This branch does not appear to have been seen by Mr. Bright. It will be remembered that it is marked doubtful in Miss Alice Hall's drawing. The branch, however, was visible, although very faint, at Namaqualand, and it might well have been visible, and yet escaped Mr. Bright's notice, at Basutoland. After comparing these drawings, and knowing the care with which they have been executed, I can have no hesitation in expressing my opinion that the cosmical character of the outer corona is proved even to the extent of more than two millions of miles from the Sun's centre, I believe to the full visible extent of the corona —more than three millions of miles from the Sun's centre.

The outline drawing marked ζ and the picture (see lithograph) were made by Mr. Wright at the Radloff station, Griqualand West. The approximate latitude and longitude are 28° 41′ 40″ south, $1^h\ 38^m\ 42^s$ [=24° 40′ 30″] east; this drawing should, therefore, represent the state of the corona very nearly 7^m after that made at Klipfontein. The position of this station I obtain from a discussion of observations made by Francis H. S. Orpen, Esq., Surveyor-General, Griqualand West, to whose party Mr. Wright was attached. I have experienced some difficulty in tracing the connection between the original outline drawing and the finished picture, and I addressed a letter to Mr. Orpen, asking for information upon the point. The following extract is Mr. Orpen's answer to that letter:—

"Surveyor-General's Office, Barkly,
"*23rd May*, 1874.

"My dear Sir,—I have just received yours of the 15th, and on receipt "of it requested Mr. Wright to come into my office, and look over it with "me. The *sketch* sent to Sir H. Barkly *was* the original one made at the "time of totality; of this I was particularly careful, knowing that you would "much rather have an original than any copy. On returning home from

Mr Wright's Picture



"our expedition, however, we inked in the sketch, following the pencil lines. "The words 'faint' or 'very faint' were marked in some spots in pencil, "but if I recollect aright were not inked in; but, although the pencil lines "and marks were rubbed out with india-rubber after the inking, I think a "close examination will show you where and what they were. The outline "of the corona represents the *extreme* outline of the corona as seen, but of "course does not imply that all within it was equally brilliant or well "defined; and where the words 'faint' &c. are written, they show where, to "a casual glance, a more or less deep indentation would appear. The "coloured drawing was made entirely from the sketch, and from *recollection* "of the colours, and of the intention of the notes 'faint' &c. There was "certainly a bluish tinge towards the outer edge of the corona, and its most "marked feature was the prominence towards × in the enclosed tracing "(which please return to me). The dotted line showed the outline as it "appeared just as totality commenced; but the radiations appeared imme-"diately afterwards to 'shoot out' to the outline shown in continuous line, "and so remained. The enclosure is a tracing made from the sketch before "sending it off. On it I have marked 'faint' &c. where I *believe* such notes "appeared on the original. These notes were not traced, merely the outline. "Your instructions regarding the preparation of the paper, plumb-line, &c. "were strictly followed, and a scale used in getting the extent of the corona, "in proportion to the Moon's disk. My entry about the sketch does not "apply to me personally, but to the party. Only Mr. Wright made one.

"I remain, my dear Sir,
"Yours faithfully,
"Francis H. S. Orpen.

"E. J. Stone, Esq., F.R.S., F.R.A.S.,
"H. M. Astronomer,
"Cape Town."

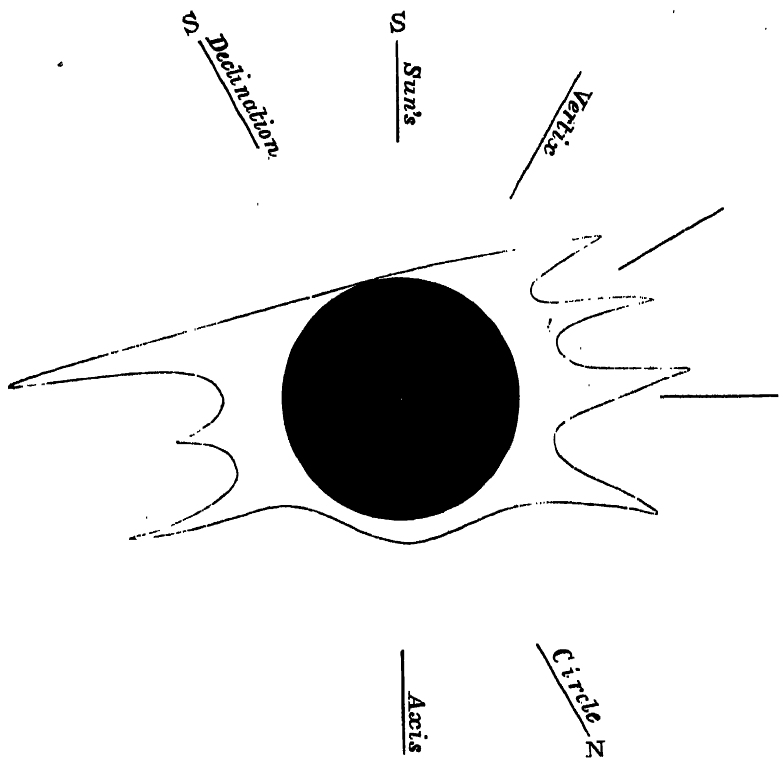
The tracing was returned to Mr. Orpen. It afforded no additional information.

It would appear, therefore, that no attempt was made to complete a drawing of the branches of the visible corona at the time of the totality, but that a boundary line was swept around it, and notes made at different parts of this boundary, such as "ray," "faint" &c., and that the picture was subsequently finished from a recollection of the intention of these notes. Some of the notes, "ray," "faint" are still visible in the original; thus the word "ray" falls exactly upon the branch F of the composite drawing; but of course no one but the person who made the drawing can judge of the exact

force intended to be given to these words, and for that we must refer to the picture. The amount of detail given in Mr. WRIGHT's picture is very great: in fact so great that probably in details it is hardly so much to be trusted as drawings made by observers who confined their attention to one or two points. As a general picture of the appearances presented it is, however, most valuable; but with extreme diffidence in offering an opinion upon such a point, I cannot regard the colour of the outer corona as correct. It appeared to me of a deadened white, and, judging from the spectroscopic observations, it should be a white tinged with green. The inner corona drawn by Mr. HENRY HALL at Namaqualand can clearly be traced. The branch D seen at Namaqualand, but marked faint and doubtful, appears in Mr. WRIGHT's drawing. This branch, it will be remembered, does not appear in Mr. BRIGHT's drawing. The general agreement between the corona as seen in Griqualand and at Namaqualand and Basutoland is striking. The inner corona A, and all the principal branches, B, C, D, E, and F, of the outer corona, seen in Namaqualand, are reproduced in Mr. WRIGHT's picture. The general agreement of the position of the branches is also very close, but the branches in Mr. WRIGHT's picture appear to be turned through about 15° from south to east more than in the Namaqualand picture. The real shift from the differences in the position of the observers, should be about 5°. It will, however, readily be seen, from the want of equality of the reference sectors in the original outlines, that discordances of 10° between this drawing and another cannot be depended upon as founded upon any real difference in the corona. The extent of the corona in Mr. WRIGHT's picture is even greater than in the drawings of Mr. BRIGHT and Miss ALICE HALL. There are two points to which further attention may, perhaps, be called in Mr. WRIGHT's picture. There is a note of an apparent change of the outer corona about branch C. From Mr. ORPEN's letter it appears, however, that the first form of the corona was only seen "just as totality commenced," and that the changed appearance was presented immediately afterwards, and so remained. I think, therefore, that no real change took place. The apparent change may easily be accounted for by supposing that at first the details of the faint corona were not all grasped, and that these became more strongly marked as the darkness and the sensitiveness of the eye of the observer increased. Such apparent changes are, I consider, thrown light upon by by what took place in Namaqualand. The second point appears important. There is around the whole corona a faint tint of light, spoken of in Mr. ORPEN's letter as a bluish tinge. The general form of this faint light con-

forms so closely to that of the corona, that I should be inclined to regard it as a halo arising from the action of the Earth's atmosphere upon the light of the corona. Such appears to have been the impression of the observers at the time. It may be mentioned, as bearing upon this point, that, although the sky was clear at the time of totality, it was clouded shortly before and after. Mr. ORPEN's party were, indeed, exceedingly fortunate, for generally over the Diamond-fields district dense clouds arose just before the totality and prevented

MR. DEGERMAN'S DRAWING. θ.



any observations of the corona being made. This appears to have been the case at Barkly or Pniel, and at Kimberley or New Rush. Two small photographs, taken by Messrs. WEBER and SEDERSTROM, some little time before and after the totality at Kimberley, show the state of the sky at this station.

A drawing, however, of the corona, was made by Mr. DEGERMAN, at a station about 13 miles from Pniel. It is marked θ. The scale is very small, but the drawing would appear to have been executed with care, and is referred

to radial lines in the manner indicated in my letter. It will be seen that this drawing represents the corona as rather less extended than the other drawings, and differs from them somewhat in the shortness and position of the ray C, at about 30°. The rays F and E are, however, laid down in positions agreeing with the other drawings, and the extraordinary compression of the corona in the direction perpendicular or nearly perpendicular to the ecliptic is confirmed. The agreement between this drawing and that of Mr. BRIGHT is very great. The smaller extent of the visible corona may have been due to clouds.

The corona was also seen by Captain MURRAY, R.N., at Hope Town. The duration was $2^m\ 5^s$. Captain MURRAY confirms the great extension of the corona in the east and west directions, but states that the time was insufficient for any trustworthy drawing.

The totality was seen by the Rev. J. DALRELL, M.B., B.D., at the Gordon Memorial Mission, Natal; approximate position, 28° 30′ south latitude, and longitude 30° 32′ east. The inner bright corona was seen, and its outline could easily have been sketched, but this was not done, because, in accordance with my instructions, attention was directed to the outer corona. A satisfactory drawing of this corona was prevented by thin slightly fleecy clouds, which intercepted the view and rendered it uncertain whether the brightness belonged to the intervening cloud or to the Sun.

The weather generally throughout the Diamond-fields district was unfavourable, or a much larger number of drawings would have been secured.

The only observations of the times of contact which have reached me sufficiently complete to repay the labour of accurate discussion have been those made by Mr. ORPEN, at the Radloff station. They consist of a first contact and the times of the commencement and ending of the totality. The first, when corrected by comparison with corresponding observations at the Observatory, gives very nearly indeed the same longitude as that which results from the observations of totality, and the resulting longitude, $1^h\ 38^m\ 42^s$, is, I should consider, very near the truth.

The following results appear to have been obtained from the South African Eclipse of 1874:

1. A confirmation of YOUNG's observation of the general or nearly general reversion of the FRAUNHOFER lines in the spectrum of the corona near the photosphere.

2. A spectroscopic examination of the outer corona, in contradistinction to the inner corona, carried to the extent of rather more than a degree from the Sun's centre, which has proved that the spectrum of the outer

corona consists of a linear spectrum of one bright line, either exclusively or sensibly, whose wave-length is 5,312 with unit of $\frac{1}{10^{10}}$ of a metre, and of an ordinary sunlight spectrum with absorption lines. The spectrum of the outer corona has been shown to fade gradually away, as the extreme visible limit of the corona is approached, and not to disappear sharply as if the extreme limit of the corona had been reached.

3. This spectroscopic examination of the outer corona, combined with the unchanged character of its principal features as seen at Namaqualand, Griqualand, and Basutoland at intervals of absolute time extending to 10^m, and at distances of more than 500 miles, proves, I venture to think, the solar origin and cosmical character of the outer corona. The want of coincidence in the positions of the general extensions of the inner corona with the main branches of the outer corona is an additional argument against the atmospheric origin of the outer corona.

4. A comparison of the drawing of Mr. Henry Hall, made at Namaqualand, and the photographs obtained in 1869 and 1871 shows the permanent character of the contraction of the inner corona in a direction parallel to, or nearly parallel to, the Sun's axis of rotation. The strongly marked character of the general contraction of the outer corona in the same direction, as seen in the Eclipse of 1874, may not improbably ultimately lead to a similar inference in the case of the outer corona also.

Travelling in Namaqualand is slow and rough; and the securing of magnetical observations at four distant stations made my month's work in Namaqualand a busy one. But the thoughtful kindness and assistance extended to me by E. J. Carson, Esq., the manager, R. T. Hall, Esq., C.E., the engineer of the Cape Copper Company, and the Rev. — Brecher, of the Missionary Station, Steinkop, made the trip one of great enjoyment. I shall ever retain the most pleasant recollections of the Eclipse expedition of 1874 to Namaqualand.

III.—*Catalogue of Micrometrical Measurements of Double Stars, made at the Temple Observatory.* By J. M. Wilson, M.A., and G. M. Seabroke, Esq.

In presenting to the Society the measures of Double Stars made at the Temple Observatory of Rugby School, during the years 1871, 2, 3, and 4, we wish to make a few remarks.

Our reason for publishing them without further delay is that Members of this Society, and others who are at work on the same subject as ourselves, may have the opportunity of comparing their measures with ours. Where they agree, there will be greater confidence in the results; and where they differ, there will be an indication that further measures are desirable. We believe that accuracy in the measures of Double Stars can only be secured by multiplying observations; observations must be taken on different nights, and by more than one observer. Proofs are not far to seek that even the most excellent observers occasionally make considerable errors in this class of observation, and we shall, on our part, feel greatly obliged to any observers whose recent measures on any of these stars differ materially from our own, if they will kindly communicate to us a list of those stars on which they recommend us to take further measures.

The stars of which measures are given in the subjoined list include most of those in Chambers's *Catalogue*, which we have found very useful. Some of these stars, however, are extremely close at present, and are beyond our power. With this as our working list we began our measures; and gradually added to it, as we went on, from Smyth's *Celestial Cycle*; selecting the not very wide doubles from that book, but not attempting to include all such doubles. Some more stars were selected, for some point of interest which they

presented, from DAWES' *Catalogue*, in vol. xxxv. of the *Memoirs of the Royal Astronomical Society*, and from his Appendix. On learning, however, that Mr. GLEDHILL, of Mr. E. CROSSLEY'S Observatory, near Halifax, was also at work on Double Stars, we entered into communication with him, and beg to acknowledge and thank him for the very great help he has constantly rendered us. Having the use of Mr. E. CROSSLEY'S excellent astronomical library, he made a selection from the stars observed by STRUVE, MÄDLER, SECCHI, and others, comprising nearly all those doubles in which there was ground to suspect motion, and thus enlarged our list. To Mr. GLEDHILL, moreover, are due all the corrections of the places of these stars, which are given for 1880, and their reputed magnitudes. The observations on these stars have been divided between Mr. CROSSLEY'S Observatory and our own, we taking the even numbers of STRUVE, and stars below 50° N. Declination, and Mr. GLEDHILL taking all others, and, when time permitted, checking our measures also. Our list, therefore, must be regarded as supplementary to his more extensive list, which is simultaneously presented to the Society.

In the present list we make no remarks on the previous measures made by others, and the results of comparing them with our own. At some future time, it is hoped that a tolerably complete list of binaries will be formed, and that our measures may prove to be of service in its formation. For this work Mr. GLEDHILL has accumulated a large amount of materials.

The instrument that we have made use of in these observations is known as ALVAN CLARK'S 8¼ inch, made for DAWES, and with which DAWES made many of his later measures. We have every reason to be content with its performance. On very fine nights, which are unhappily of rare occurrence, it divides down to half a second or thereabouts, and the clock-work is thoroughly satisfactory. It has not been out of order for a day since we had it. The only micrometer we have used is a parallel wire micrometer by Dollond, also made for DAWES. The value of the readings on the circular screw heads for distance-measures is, with our focal length, 5·33 graduations to 1″. This constant was determined by taking transits of both equatorial and non-equatorial stars, and also by measuring the distances of some of the stars in the *Pleiades*, whose positions are given with great accuracy by BESSEL. It may be relied upon, we believe, to the second decimal place ; and we have adopted 5·3 as the basis for our reductions. Further, with scarcely half a dozen exceptions, all the measures have been made with the same magnifying power, apparently about 400.

We have assigned no weights to our measures, from a conviction that

any estimate we could make would be delusive. The agreement *inter se* of measures made on one night is no proof that they are correct. It would be easy to give instances from the present catalogue in which measures carefully made by both of us on one night agreed very fairly, and yet differed materially from the equally concordant results obtained by us on another night. Distance-measures especially are affected in this way, probably by the variation in the state of the atmosphere. Nor did we find that to take many readings on each night repaid us for the additional expenditure of time by additional certainty. Readings taken on the same night have a great tendency to confirm one another: they may be scrupulously independent, but the eye forms a judgment of the distance or position, and the readings confirm that judgment. Six readings on three nights are worth twice as much as six readings on one night. Our readings, therefore, were few, but independent; and where they confirmed one another, or differed slightly, we did not generally repeat them often. Four measures of position and two of distance were perhaps the most frequent number of measures made in each case. There appears to be a tolerably systematic difference between us in our measures of the distance of stars under $3''$, W.'s measures exceeding S.'s by about $0''\cdot1$ to $0''\cdot2$. On wider stars not quite so great a difference is observable.

We can only offer these observations as the work of amateurs and beginners. They were made principally by ourselves; but we have derived much assistance, more than is shown by the number of his measures, from Mr. PERCY SMITH, F.C.S. (Sm.); and several members of the School learned to take trustworthy and good measures. Those to whom we owe most are Mr. A. M. WORTHINGTON (A.M.W.); Mr. L. MAXWELL (M.); Mr. F. C. HOUGHTON (H.); and Mr. W. LARDEN (L.). Others, including some gentlemen who are not members of the School, whose initials appear occasionally in the list, are Mr. C. H. KER (K.), Mr. J. B. FELL (F.), Mr. R. S. GUNNERY (G.), Mr. C. H. WILSON (C.H.W.), Mr. C. P. RIDLEY (R.), Mr. S. G. TREMENHEERE (T.), and Dr. DUKES (D.).

If this work should not seem very extensive to produce as the result of $3\frac{1}{2}$ years' possession of a telescope, we would plead that we ought to be judged leniently; for the hours within which we can observe are but few. One of us can never, and the other can but very seldom, begin work before half-past nine; and regular early morning engagements prevent our making much use of the hours after midnight. Moreover, a single observer cannot now turn the roof of the Observatory round, and we therefore cannot begin work until two of us are free. And it must be remembered that our work is

much interrupted by visitors. There are few fine evenings on which we have not visitors till 10.30, and the Temple Observatory is intended for their use and instruction. The telescope was given to Rugby School, as the inscription on it states:

> Quo cœli miracula explorent,
> Scientiam augeant, exerceant ingenia;

and the first and third of these uses is therefore as steadily kept in view as the second. Hence, during part of the observing hours, the telescope is often directed to the Moon, and planets, and nebulæ, and clusters, and comets, as well as to doubles. And again we have not altogether limited our work to double stars. We have made many drawings of *Mars*, and *Venus*, and *Jupiter*, and have spent some time on lunar and stellar photography, and on the spectroscope.

In fine, we think we have done as much as we could. How far the observations have value must be left to others to decide; but they are at any rate *bonâ fide*, and independent and careful, and as such, and as being the best in our power, are offered with all respect for the acceptance of the Royal Astronomical Society.

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Dec. 1880.	Position-Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Observer.	Remarks.
				h m s	° ′ ″	°		″				
1		1	8, 10	0 2 39	36 32 53	286·6	4	10·2	3	73·86	W. S. L.	
2	316 B Cephei	.	5½. 6	0 2 42	79 2 38	...	...	...	...	72·92	W. S.	Less than 0″·4; night [very good. Also 73·82.
3	318 B Cephei	13	6, 6½	0 9 25	76 17 3	103·1	9	0·5	est.	·5	W. & S.	
4	... ...	...	...	...	...	100·7	7	...	...	73·3	S.	
5	38 Piscium	22	8, 8	0 11 13	8 12 23	239·7	4	4·54	2	·86	W.	
6	... ...	...	...	...	...	236·9	5	4·64	2	·93	W. & S.	
7	... ...	...	...	...	...	238·7	5	4·38	2	74·91	S. Sm.	
8		23	8, 10	−0 11 20	0 21 4	352·8	4	...	...	73·86	W.	
9		...	...	...	...	353·9	2	...	...	·86	L.	
10		...	...	...	...	353·2	5	8·9	1	74·91	S. & Sm.	
11	49 Piscium	32	7, 10	0 24 33	15 22 29	106·6	3	16·6	2	73·93	S.	
12	51 Piscium	36	5, 9	0 26 12	6 17 33	82·7	5	28·4	1	·86	W. S. L.	Unsteady.
13	AB	41	8, 11, 11	0 28 38	38 30 24	189·6	5	...	...	·86	W. S.	
14	AC	...	...	...	...	252·3	3	...	...	·86	W. S.	
15		44	8, 9	0 31 56	40 19 35	264·1	5	8·9	4	72·00	S.	
16		...	...	...	...	264·0	5	9·3	2	·85	W.	} Windy night.
17		...	...	...	...	265·1	2	...	...	·85	M.	
18		...	...	...	...	263·6	5	...	...	·86	W.	
19		...	...	...	...	263·0	3	9·6	1	74·86	S.	Cloudy.
20	63 B Cassiopeiæ	45	7, 10	0 32 7	46 17 49	85·4	5	11·1	2	73·86	W. S.	
21	... ...	...	...	...	...	87·3	3	10·1	3	74·91	S. Sm.	Very difficult.
22	... ...	...	...	...	...	87·0	4	10·9	2	·93	W. S.	Hazy.
23	55 Piscium	46	5, 8	0 33 36	20 46 50	194·2	4	6·5	2	73·93	S.	
24		54	9, 10	0 37 55	32 52 48	195·0	2	18·1	2	·93	W. S.	
25		55	8, 8·8	0 37 55	32 57 40	325·6	4	1·88	2	·93	W. S.	
26	P. 0. 181	59	7, 8	0 41 11	50 47 24	149·0	4	2·14	2	·83	W. S.	Distance by S.
27	Cassiopeiæ η	60	4, 6	0 41 43	57 11 9	140·9	8	...	...	71·93	W. S.	
28	... ...	...	...	...	...	...	...	6·0	4	72·01	S.	
29	... ...	...	...	...	...	142·3	7	...	...	73·06	W. S.	B very faint. Hazy.

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Dec. 1880.	Position-Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Observer.	Remarks.
				h m s	° ′ ″	°		″				
30	Cassiopeiæ η	60	4, 6	0 41 43	57 11 9	144·7	7	6·22	4	73·83	W.	
31	... ...	...	...	...	...	...	...	6·64	2	...	S.	
32	... ...	...	...	...	...	...	...	6·23	2	...	Sm. & H.	
33	... ...	...	...	...	...	146·0	6	5·8	3	74·90	W. S.	
34	65 Piscium	61	6, 6	0 43 26	27 3 23	118·0	4	4·50	2	73·93	S.	Night very good.
35		63	8, 11	0 43 56	11 10 43	221·5	6	13·0	2	74·93	W. S.	Bad definition.
36		69	8, 10	0 47 51	83 2 2	10·0	3	22·4	1	·93	W.	Bad night.
37	36 Andromedæ		6, 6·2	0 48 32	22 58 45	352·3	4	1·36	4	72·03	S.	
38	... ...		...	...	...	355·0	7	1·14	3	·88	W. S. M.	
39	... ...		...	...	...	354·1	4	1·20	2	·88	W.	Night hazy.
40	... ...		...	...	...	353·1	7	1·34	3	73·81	W. & Sm.	Definition perfect.
41	... ...		...	...	...	355·9	5	1·43	2	74·93	W. & Sm.	Bad definition.
42	... ...		...	...	...	356·0	6	1·38	2	·94	S. & Sm.	Very fair definition.
43	P. o. 251	80	8·2, 9·4	0 53 15	0 8 11	312·9	8	20·1	2	71·85	W.	Night not good.
44	... ...	...	...	...	...	311·6	4	19·7	8	·90	W. & S.	
45	... ...	...	...	...	...	311·7	4	19·9	4	72·00	S.	
46	... ...	...	...	...	...	311·8	7	18·4	2	·88	W. S. M.	Distance doubtful.
47	... ...	...	...	...	...	311·9	3	20·3	2	73·81	W. S.	Definition good.
48	... ...	...	...	...	...	312·9	6	20·0	5	74·93	W. S.	Haze.
49	26 Ceti ...	84	7, 9	0 57 38	0 43 27	253·0	4	16·0	2	73·93	S.	
50		85	8, 9·5	0 58 20	−5 56 56	159·7	4	26·7	3	·93	W. S.	
51	H iii. 75	86	8, 8	0 58 43	−6 6 44	163·4	4	12·6	2	·93	W. S.	Not very satisfactory.
52	77 Piscium	90	5·9, 6·8	0 59 36	4 16 16	83·3	2	33·3	2	·93	W.	
53	160 B Ceti	91	6·7, 7·5	1 1 3	−2 22 26	321·4	4	4·0	2	·81	W. Sm.	Hazy.
54	... ...	...	...	...	...	322·1	4	4·0	2	74·93	W. S.	Hazy.
55	... ...	...	...	...	...	322·2	5	3·8	4	·93	S.	Better.
56	ϕ Piscium	99	5, 10	1 7 14	23 56 56	226·0	5	7·6	4	73·89	W. S.	Distance doubtful.
57	ζ Piscium	100	6, 8	1 7 27	6 56 30	63·7	3	24·7	2	·89	W. S.	

58			101	7, 9	1 7 54	− 8 15 27	342·2	5	...	...	73·89	W. S.	
59			...	...	...	...	340·8	3	22·3	2	74·93	W. S.	
60	194 B Andromedæ		108	7, 10	1 11 59	36 45 18	63·7	4	6·3	2	73·89	W. Sm. L.	Unsatisfactory.
61	... ...		...	...	...	...	62·4	3	6·0	2	·93	W.	Very good definition.
62	42 Ceti ...		113	6·2, 7·2	1 13 40	− 1 8 20	346·2	4	1·35	4	72·07	S.	
63	... ...		...	...	...	...	349·5	4	1·24	2	73·01	S.	Very unsteady.
64	... ...		...	...	...	...	350·7	3	1·63	2	·81	W. S.	In haze.
65	... ...		...	...	...	...	348·0	8	1·45	2	74·93	W. S. Sm.	In haze.
66	ψ Cassiopeiæ	AB	117	4½, 9, 11	1 17 26	67 30 12	105·5	2	29·8	4	73·83	W. S.	
67	... ...	AC	...	...	...	...	255·8	6	3·06	4	·83	W. S.	Faint and difficult.
68			122	7, 9	1 20 41	2 54 49	328·2	5	6·2	3	·81	W. S.	Haze, very uncertain.
69			...	...	...	...	330·2	4	6·2	3	·93	W. S.	
70			125	7, 9	1 20 50	− 0 45 49	356·3	2	...	...	·87	W.	
71			...	...	...	...	354·8	3	30·3	1	74·93	W. S.	
72		AB	132	8, 9, 10	1 25 35	16 20 18	356·0	2	...	...	73·89	W.	A looks like 7 mag.
73		AC	...	...	...	...	222·5	3	...	...	·89	W.	
74	219 B Andromedæ	AB	133	7, 10½, 10, 10, 9, 9½	1 25 55	35 13 41	185·0	10	3·04	2	·89	W. S. Sm. L.	Difficult, readings differ.
75	... ...	...	...		...	...	182·0	...	...	...	74·93	W. S.	Could not measure, night [bad.
76	... ...	AC	...	...	...	...	193·9	2	...	...	·93	W. S.	Hazy.
77	... ...	CD	...	...	...	...	351·5	4	4·75	2	73·89	W. S.	A difficult group.
78	... ...	...	...	...	...	...	351·7	2	...	...	74·94	W. S.	
79	... ...	AE	...	...	...	...	1·0	1	...	...	73·89	W.	
80	... ...	...	...	...	...	...	0·3	2	...	...	74·93	W. S.	
81	... ...	EF	...	...	...	...	300·0	1	...	...	73·89	W.	
82	... ...	...	...	...	...	...	300·7	2	...	...	74·93	W. S.	
83	100 Piscium		136	7, 8	1 28 29	11 56 41	79·2	5	16·4	2	73·89	W. S.	Distance doubtful.
84	P. I. 123	AB	138	6·2, 7·2	1 29 46	7 1 53	31·0	4	1·42	4	72·07	S.	
85	... ...	...	...	...	...	...	32·9	4	1·14	2	73·01	S.	
86	... ...	...	...	...	...	...	33·2	7	1·36	4	·81	W. & S.	
87	... ...	...	...	...	...	...	29·9	7	1·59	3	74·95	W. & S.	
88	... ...	AC	...	...	...	...	70·7	2	...	...	·95	W. & S.	Very bad night.
89			142	7, 7½	1 33 28	14 38 54	327·2	3	19·0	2	73·87	W. S.	
90			155	8, 8	1 37 54	8 53 3	330·9	3	4·5	4	·89	W. & S.	Not good measures.

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Dec. 1880.	Position-Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Observer.	Remarks.
				h m s	° ′ ″	°		″				
91		158	8, 8·8	1 39 50	32 33 48	257·5	4	2·05	4	73·89	W. S.	
92		164	8·7, 9·0	1 42 14	33 27 49	95·8	3	9·6	3	·93	W. S.	
93		182	7, 7	1 47 58	60 41 35	301·6	6	4·1	4	72·05	S. & K.	
94	P. I. 209	186	7·5, 7·5	1 49 41	1 15 10	...	...	...	...	73·93	W. S.	Very close; less than 0″·5.
95	α Piscium	202	3, 5·3	1 55 50	2 11 3	324·4	4	3·3	4	72·07	S.	
96	... ...	...	...	...	...	324·2	3	3·16	2	73·93	W. S.	
97	γ Andromedæ	205	3, 8	1 56 32	41 45 17	64·5	4	10·45	4	72·03	S.	
98	... ...	...	...	...	...	64·4	2	10·50	2	73·81	W.	
99	γ² Andromedæ	[38]	8, 8½	...	...	87·7	4	...	...	72·03	S.	Only elongated; beyond our power, except on excellent nights.
100	... ...	...	...	...	...	95·9	10	0·5	est.	73·81	W. S.	Very difficult.
101	10 Arietis	208	6, 8·5	1 56 50	25 21 28	41·0	4	1·58	4	72·08	S.	
102	... ...	...	...	...	...	43·1	8	1·30	3	·85	W. & S.	
103	... ...	...	...	...	...	40·1	4	1·32	2	73·93	W. & S.	
104	ι Trianguli	227	8½, 8½,	2 5 25	29 44 30	66·1	4	6·7	2	·94	W.	Definition very good.
105	259 B Andromedæ	228	6·8, 7·2	2 6 21	46 55 29	308·7	4	...	...	72·04	W.	
106	... ...	...	...	...	...	309·0	3	0·77	2	73·93	W. & S.	
107	66 Ceti ...	231	6, 7·8	2 6 39	− 2 57 13	230·4	3	16·0	2	·94	W.	Definition very good.
108		254	9, 9·5	2 14 48	23 4 47	342·8	4	12·7	2	·93	W. S.	
109		...	...	...	...	343·6	4	12·9	2	·97	S.	Haze.
110		...	...	...	...	344·0	4	...	...	74·00	S.	Haze.
111	ι Cassiopeiæ AB	262	4, 7, 7½	2 19 10	66 51 46	265·0	7	2·	3	72·04	W. & S.	Distance difficult.
112	... ...	...	...	...	...	266·0	2	2·25	2	·92	W. & S.	Night very good.
113	... ...	...	...	...	...	264·4	4	2·04	2	73·06	W. & S.	Definition bad.
114	... ... AC	...	...	...	...	109·0	4	7·81	2	72·92	W. & S.	
115	P. II. 89 ...	269	8½, 11	2 21 9	29 20 8	347·1	3	1·27	2	73·94	W. & S.	In fog; very faint.
116	... ...	...	...	...	...	345·2	4	1·7	2	·97	S.	Hazy.
117	... ...	...	...	...	...	345·6	4	1·29	2	74·00	S.	Hazy.
118		276	9, 9	2 26 20	5 48 17	257·9	6	2·47	2	73·93	W. S.	
119		...	...	...	...	260·0	4	...	...	·97	S.	Very hazy.

120			276	9, 9	2 26 20	5 48 17	259.7	4	2.07	2	74.00	S.	Bad definition.
121			280	7, 8	2 28 8	− 6 9 48	346.4	3	3.72	2	73.93	W. S.	
122	33 Arietis		289	6, 8	2 33 40	26 32 47	0.9	4	29.1	2	.94	W. & S.	Foggy.
123	... ...		...	...	...	...	359.6	3	28.7	2	.97	S.	Very shaky.
124	... ...		...	...	...	...	359.0	4	...	...	.99	S.	Ditto.
125	84 Ceti ...		295	6, 10	2 35 4	− 1 12 11	324.1	4	4.7	4	72.08	S.	
126	θ Persei ...	AB	296	5, 9, 9½, 11	2 35 58	48 43 20	296.0	3	16.5	2	73.93	W. & S.	
127	... ...	AC	...	...	...	...	215.3	3	...	...	.93	W. & S.	
128	... ...	AD	...	...	...	...	16.6	1	...	...	.93	W.	
129	114 B Arietis		305	7. 8	2 40 41	18 51 32	319.4	4	2.7	4	72.04	S.	
130	ε Arietis ...		333	5. 6	2 52 21	20 51 40	196.3	4	1.26	4	71.95	S.	Satisfactory.
131	... ...		...	...	...	...	200.5	5	1.5	3	72.17	W.	Twilight.
132	... ...		...	...	...	...	198.7	12	1.69	3	.86	W. & F.	
133	... ...		...	...	...	...	197.5	9	1.10	3	.92	W. & S.	Very good; difficult.
134	... ...		...	...	...	...	200.5	4	1.44	2	73.14	W.	Night good.
135			380	9, 10	3 15 17	8 19 47	73.5	4	1.26	2	.93	S.	
136			...	...	...	...	75.4	2	...	...	74.00	S.	Doubtful.
137			...	...	...	...	75.3	2	1.3	est.	.00	S.	
138			408	8, 8.2	3 24 40	− 4 41 3	159.8	5	1.44	5	73.93	W. Sm. L.	
139			...	...	...	...	160.8	5	1.43	2	74.00	S.	Definition very bad.
140	7 Tauri ...	AB	412	6.6, 6.7, 9½	3 27 20	24 3 44	227.0	7	...	...	72.14	S. & K.	Too close for distance.
141	... ...	...	...	...	...	...	239.7	15	0.4	est.	73.14	W. & S.	Mean of 5 nights; beyond our power.
142	... ...	...	...	...	...	...	254.1	4	...	...	74.01	S.	
143	... ...	AC	...	...	...	...	61.1	2	...	...	72.17	W.	
144	... ...	...	...	...	...	...	60.5	4	23.2	2	.86	W. & S.	
145	... ...	...	...	...	...	...	60.5	1	...	...	.92	W. & S.	
146	... ...	...	...	...	...	...	60.9	3	...	...	73.14	W.	
147	... ...	...	...	...	...	...	60.3	5	22.3	2	.93	S.	
148	... ...	...	...	...	...	...	60.6	2	22.9	1	74.00	S.	
149	P. III. 98...	...	422	6.2, 8	3 30 38	0 11 54	241.3	4	5.9	5	71.95	S.	A orange; B blue.
150	... ...		...	...	...	...	241.2	5	6.2	2	.86	W. & S.	
151	... ...		...	...	...	...	241.3	5	6.3	2	73.93	W. & S.	
152	49 Hev. Cephei		460	5.5, 6.5	3 49 57	80 22 7	24.4	6	0.7	est.	72.92	W. & S.	Satisfactory.

Ref. No.	Name of Star.		Struve's No.	Mags.	R.A. 1880.	Dec. 1880.	Position-Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Observer.	Remarks.
					h m s	° ′ ″	°		″				
215	12 Lyncis	AB	948	5·3, 6·3, 7·5	6 35 38	59 33 48	131·4	4	1·84	4	72·08	W. & S.	
216	... ...	...	...	...	...	...	135·7	4	1·27	2	73·19	S.	
217	... ...	...	...	...	...	...	134·6	5	1·56	1	·24	W.	Two visitors assisted; [def. very good.
218	... ...	...	...	...	...	...	135·8	2	...	...	·25	S.	Troublesome; third star [perplexing.
219	... ...	...	...	...	...	...	133·3	3	...	...	·25	W.	
220	... ...	...	...	...	...	...	133·4	3	1·7	1	·29	S.	
221	... ...	AC	...	...	...	...	306·3	8	8·58	4	72·08	W. & S.	
222	... ...	...	...	...	...	...	307·9	4	7·2	2	73·19	S.	
223	... ...	...	...	...	...	...	305·8	5	8·76	1	·24	W.	
224	... ...	...	...	...	...	...	307·7	2	...	...	·25	S.	
225	... ...	...	...	...	...	...	306·5	3	...	...	·25	W.	
226	... ...	...	...	...	...	...	307·2	3	8·6	1	·29	S.	
227	15 Monocerotis	AB	950	6¼, 9, 15	6 34 22	10 0 25	211·8	8	2·62	4	72·92	W. S.	Readings difficult, night [good.
228	... ...	...	...	...	...	...	210·0	5	2·8	1	73·16	W. & S.	Night hazy.
229	... ...	...	...	...	...	...	210·7	5	2·9	2	74·13	W. & S.	
230	... ...	AC	...	...	...	...	14·7	5	15·3	2	·13	W. S. Sm.	Distance difficult; C looks [like 11th mag.
231	Sirius ...			1, 8	6 39 53	−16 32 6	65·0	3	11·29	2	73·93	W. & S.	Distinctly seen.
232	14 Lyncis		963	6, 6	6 42 30	59 35 29	62·8	4	0·57	2	·19	S.	
233	... ...		...	...	...	...	59·0	4	0·69	1	·24	W.	Night unfavourable.
234	... ...		...	...	...	...	63·8	6	...	...	·25	W. & S.	Very bad night.
235	... ...		...	...	...	...	63·7	4	...	...	·29	S.	
236			966	8, 10·2	6 43 51	40 5 51	...	...	...	...	74·14	Sm.	Could not see companion.
237			...	...	...	...	...	...	...	...	·17	S.	Ditto.
238	38 Geminorum		982	6, 8	6 47 52	13 19 54	165·3	5	6·42	2	72·13	W.	
239	... ...		...	...	...	...	165·7	6	6·29	2	·08	W. & S.	
240	... ...		...	...	...	...	166·2	6	...	...	·12	W.	Two nights.
241	... ...		...	...	...	...	166·3	2	5·7	1	73·16	W.	
242	... ...		...	...	...	...	165·1	5	6·50	4	74·13	W. & S.	Very indistinct; 4 hours [from meridian.
243	... ...		...	...	...	...	165·7	4	6·31	2	·17	W.	

244		986	8, 9	6 48 19	9 39 4	165·5	5	5·30	2	74·13	S. & M.	Shaky.
245		...	...	...	...	164·5	6	5·25	3	·17	W. S. Sm.	
246	μ Canis Majoris	997	5, 8½	6 50 37	−13 53 17	343·5	4	3·4	2	72·14	S.	A orange; B blue.
247	... ...	...	...	...	...	341·2	9	3·42	2	74·13	W. S. & Sm.	Very bad definition, and unsteady.
248	... ...	...	...	...	...	...	...	3·25	3	·18	S. Sm.	
249		1008	8½, 10	6 54 9	26 44 33	268·7	4	2·03	2	·13	W. Sm.	Bears illumination well.
250		1016	7·9, 8·9	6 59 1	−11 20 41	167·8	5	5·6	2	·18	S. & Sm.	Probably in considerable error.
251		1021	9, 10	7 1 21	38 40 20	10·2	5	4·44	2	·18	S. Sm.	
252		1032	7, 10·3	7 4 50	48 42 1	106·9	5	2·38	2	·17	W. & S.	Excessively faint.
253		1037	5, 8½	7 5 21	27 25 47	316·9	7	1·40	3	72·16	W. & S.	
254		...	...	...	...	315·5	3	...	...	·92	W. & S.	Very unsatisfactory.
255		1060	8, 9	7 10 22	− 9 3 28	25·3	4	7·02	2	74·17	W. S. Sm.	
256	δ Geminorum	1066	3, 8	7 12 57	22 12 12	204·0	7	6·74	3	72·17	W. & S.	
257	... ...	...	...	...	...	204·0	2	...	...	·18	W.	Definition very bad.
258	... ...	...	...	...	...	203·7	7	7·2	3	73·14	W. & S.	Very good definition.
259	... ...	...	...	...	...	204·3	4	7·1	3	74·14	W. & S.	Dense haze; B just visible.
260		1074	7·8, 8·2	7 14 21	0 37 36	134·2	7	0·85	2	·14	W. S. Sm.	Just divided.
261		1076	9½, 9½	7 14 42	4 16 51	111·9	7	2·83	2	·14	W. S.	Very faint and difficult.
262		1084	7, 10	7 18 3	− 3 44 45	286·8	6	11·7	2	·14	W. & S.	Difficult; moonlight and haze.
263		1104	6·7, 8·3	7 23 55	−14 44 19	314·0	6	2·55	2	·17	W. & S.	Satisfactory.
264	Castor ...	1110	2, 2·4	7 26 57	32 9 10	237·2	7	5·8	3	72·20	W. S. A. M. W.	
265	... ...	...	...	...	...	238·2	5	...	...	·26	S.	
266	... ...	...	...	...	...	238·9	4	...	...	·27	S.	
267	... ...	...	...	...	...	237·7	4	6·1	...	·38	W.	Daylight.
268	... ...	...	...	...	...	237·0	7	...	...	·86	W.	Bad definition.
269	... ...	...	...	...	...	237·9	5	5·6	2	73·24	W. & H.	Low power used.
270	... ...	...	...	...	...	236·9	4	5·5	3	74·12	W. S. Sm.	Bad definition.
271	... ...	...	...	...	...	237·0	6	5·7	3	·14	W.	Thick fog; definition very good.
272		1114	8, 9	7 27 8	9 32 50	54·5	3	5·9	1	·14	W. & S.	Moonlight; cloud coming on.
273		...	...	...	...	55·3	4	6·5	2	·17	W. & S.	Definition fairly good.
274	P. VII. 170	1126	7, 7·7	7 33 44	5 30 28	140·2	4	1·45	3	·17	W. & S.	In field with *Procyon*.
275		1132	8, 9	7 36 12	− 3 14 14	235·7	5	20·6	2	·18	S. & Sm.	
276		1142	8. 10	7 41 39	13 42 58	258·1	4	22·8	1	·17	W. & S.	Difficult.

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Dec. 1880.	Position-Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Observer.	Remarks.
				h m s	° ′ ″	°		″				
277	5 Navis ...	1146	5, 7	7 42 20	−11 53 55	15·8	9	3·7	2	74·18	S. & Sm.	
278		1157	8, 8·3	7 48 31	− 2 28 54	257·7	4	1·00	1	72·17	S.	
279		...	...	...	...	256·5	2	...	...	·14	W.	Very faint and misty.
280		1162	8, 9½	7 50 43	13 33 27	327·0	5	10·11	2	74·17	W. S. Sm.	Lifficult.
281		1178	9, 9	7 57 47	−12 51 54	330·2	11	4·51	2	·18	S.	Very difficult.
282	85 B Lyncis	1187	7, 7·6	8 1 54	32 34 18	54·3	5	2·14	8	72·27	S.	
283	... ...	...	...	...	...	53·5	4	1·95	4	·30	S.	
284	ζ Cancri ... AB	1196	5, 5½, 7½	8 5 19	18 0 42	168·6	4	0·78	4	·18	W.	Definition perfect.
285	... ...	...		...	...	169·3	3	0·63	2	·19	W.	Ditto.
286	... ...	...	...	...	...	165·5	6	...	...	·25	W.	Not so good.
287	... ...	...	...	...	...	150·9	25	0·5	est.	73·22	W. & S.	Mean of obs. 4 nights.
288	... ...	...	...	...	...	141·2	5	0·5	est.	74·17	W. S. Sm.	In contact.
289	... ...	...	...	...	...	142·2	4	0·67	2	·17	W.	Unsteady.
290	... ...	...	...	...	...	140·6	3	...	...	·20	W.	Very unsteady.
291	... ... AC	...	...	..	...	133·8	4	5·87	2	72·18	W.	
292	... ...	...	...	...	...	133·3	1	5·63	1	·19	W.	
293	... ...	...	...	...	...	131·2	2	5·85	1	·25	W.	Definition imperfect.
294	... ...	...	...	...	...	132·3	14	5·43	4	73·22	W. & S.	Mean of 4 nights.
295	... ...	...	...	...	...	132·0	2	...	...	74·17	W. & S.	
296	... ...	...	...	...	...	132·2	2	...	...	·17	W.	
297	P. VIII. 13	1202	8, 10	8 6 59	11 12 42	326·5	3	2·1	2	73·22	W. & S.	
298	... ...	...	...	...	...	326·6	2	2·09	1	·24	W.	Small star flashing.
299	... ...	...	...	...	...	324·2	6	2·09	1	74·14	Sm.	
300		1212	8, 10	8 10 35	31 12 15	236·8	5	4·90	3	·17	W. & S.	Unsteady.
301		...	...	...	...	238·2	4	5·25	2	·18	W.	Ditto.
302		...	...	...	...	235·8	5	5·12	1	·24	W. & S.	Fair.
303		1216	7, 7½	8 15 15	− 1 13 12	170·0	est.	...	...	73·19	W.	Dist. less than ζ Cancri.
304		...	...	...	...	168·7	2	0·4	est.	·24	W.	
305		...	...	...	...	...	...	...	...	74·14	W.	Could not divide.

306			1216	7, 7½	8 15 15	− 1 13 12	162·0	5	0·3	est.	74·17	W. & S.	Not separated; only a [guess.
307	ν Cancri ...		1224	6, 7	8 19 32	24 55 48	41·8	5	5·9	2	·17	W. S. L.	Satisfactory.
308	... ...		...	...	...	...	41·4	2	5·9	2	·18	W.	
309			1228	8, 8½	8 20 22	27 57 23	349·8	3	9·5	3	·17	W. & S.	
310			...	...	...	...	351·1	3	9·4	2	·18	W. & S.	
311			1230	8, 10	8 21 38	17 14 57	192·7	4	...	...	·17	W. & S.	Unsatisfactory; hazy.
312			...	...	...	...	193·2	5	30·6	2	·18	W. & S.	Very unsteady.
313			1263	7, 7½	8 37 16	42 8 12	18·4	4	...	...	72·25	W.	
314			...	...	...	...	18·2	4	35·6	2	·30	S.	
315			...	...	...	...	18·1	3	...	...	73·19	W.	
316			1264	9, 9	8 36 24	− 7 58 16	270·7	4	5·9	2	74·17	W. & S.	Distance uncertain.
317	ε Hydræ ...		1273	4, 9	8 40 26	6 51 37	216·2	5	3·28	2	72·19	W.	Definition good.
318	... ...		...	...	...	...	219·3	5	3·18	3	73·19	W.	
319	... ...		...	...	...	...	219·3	1	...	...	·19	S.	
320	... ...		...	...	...	...	216·7	6	3·33	3	74·18	W. & S.	
321	σ^4 Cancri		1298	6, 8	8 54 3	32 43 17	136·6	4	4·50	2	·17	W. & S.	In haze; moonlight.
322	... ...		...	...	...	...	136·1	6	4·49	4	·18	W. & S.	Definition poor.
323	... ...		...	...	...	...	137·0	...	...	...	·24	W.	Definition good.
324			1300	9, 9½	8 54 38	15 44 59	203·4	4	4·83	2	·18	S.	
325			...	...	...	...	203·4	6	4·5	3	·18	W. S. Sm.	
326	σ^2 Ursæ Majoris		1306	6·3, 9·5	8 59 51	67 37 22	249·5	4	2·85	1	72·28	S.	Very unsteady; distance [a guess.
327	... ...		...	...	...	...	246·7	4	3·07	4	·30	S.	
328	... ...		...	...	...	...	249·8	4	3·20	1	73·24	W.	B deep red; bad def.
329	... ...		...	...	...	...	246·8	4	3·20	2	·29	S.	Definition good.
330		AB	1316	8, 11, 10	9 1 56	− 6 39 7	...	...	...	...	·23	W.	Failed entirely.
331		...	...	...	...	...	137·5	2	6·18	1	74·17	S.	
332		...	...	...	...	...	142·0	4	...	...	·17	W. & L.	Very difficult.
333		AC	...	...	...	...	154·8	3	9·5	1	·17	S. & Sm.	Very difficult; beyond our [power.
334		...	...	...	...	...	160·8	3	...	...	·17	W. & L	
335			1322	8, 8	9 5 59	17 1 5	53·9	4	2·04	2	·17	W. & S.	Difficult and doubtful.
336			...	...	...	...	55·2	9	1·79	2	·18	W. S. L.	
337	38 Lyncis		1334	4, 6·7	9 11 23	37 18 45	238·2	5	2·95	1	72·21	{ W. S. A.M.W.	
338	... ...		...	...	...	...	239·8	4	2·6	2	73·19	W. & S.	

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				h m s	° ′ ″	°		″				
339	38 Lyncis	1334	4, 6·7	9 11 23	37 18 45	238·0	4	2·99	2	74·18	W. & S.	
340	157 B Lyncis	1338	6·7, 7·2	9 13 28	38 41 49	145·8	4	1·87	4	72·27	S.	
341	... ...	...	...	...	...	147·7	8	1·46	3	73·19	W. & S.	
342	... ...	...	...	...	...	147·6	2	...	...	·23	W. & S.	
343	... ...	...	...	...	...	147·8	6	1·57	3	74·17	W. S. Sm.	
344	116 B Hydræ	1348	7·5, 7·5	9 18 10	6 52 3	323·8	5	1·78	3	72·19	W.	
345	... ...	...	...	...	...	325·3	4	1·61	2	·26	S.	
346	... ...	...	...	...	...	326·1	4	1·70	2	73·22	W. & S.	
347	... ...	...	...	...	...	326·1	2	1·7	1	·24	W.	
348	... ...	...	...	...	...	326·2	11	1·69	4	74·18	W. S. Sm.	
349	ω Leonis ...	1356	6·1, 8·5	9 22 2	9 34 46	65·3	4	0·57	2	72·18	W.	Never separated com- [pletely.
350	... ...	...	...	...	...	67·3	5	0·4	est.	·19	W.	
351	... ...	...	...	...	...	53·8	2	...	...	73·23	S.	
352	... ...	...	...	...	...	58·7	2	...	...	·23	W.	Just divided at times.
353		1357	7, 10½	9 22 29	− 9 27 48	52·0	2	...	...	·24	W.	
354		...	...	...	...	51·1	2	7·5	2	·25	W.	Definition good.
355		...	...	...	...	50·0	5	7·4	1	74·17	W. & S.	Very difficult.
356	P. IX. 161	1377	8, 11	9 37 13	3 10 34	135·5	2	...	...	73·23	W. & S.	Barely seen.
357	... ...	...	...	...	...	140·5	1	...	...	·24	W.	Very difficult.
358	... ...	...	...	...	...	134·4	1	...	...	·25	W.	Distinctly seen for 1st [time.
359	... ...	...	...	...	...	139·2	6	4·0	est.	74·20	W. S. Sm.	Very difficult.
360	φ Ursæ Majoris	[208]	5, 5·2	9 43 42	54 38 0	...	...	...	...	73·24	W.	Could not divide or notch [it.
361	8 Sextantis, A.C. 5.		6, 6·5	9 46 34	− 7 32 9	...	...	...	...	72·19	W.	Failed to divide when [ζ Cancri was clearly div.
362		1404	9, 9	9 58 11	− 1 6 38	294·7	5	6·0	2	74·20	W. S. Sm.	
363		...	...	...	...	294·7	4	6·4	2	·22	W. S.	
364	γ Leonis ...	1424	3, 4·5	10 13 20	20 27 2	113·0	4	3·78	3	71·48	{ W. S. A.M.W.	
365	... ...	...	...	...	...	112·6	4	3·36	2	72·19	W.	Triangular discs.
366	... ...	...	...	...	...	112·5	5	3·50	2	73·23	W.	Satisfactory.
367	... ...	...	...	...	...	112·8	4	3·43	2	74·20	W. & Sm.	Woolly; measures almost [worthless.

368	145 B Leonis	1426	8, 7·5, 9	10 14 15	7 2 7	...	...	...	...	74·21	W.	Could not divide AB.
369		1429	8·6, 8·8	10 18 22	25 13 47	265·8	2	...	...	73·24	W.	Strange difference in [readings.
370		...	...	...	...	260·8	3	0·95	1	·24	S.	
371		...	...	...	...	...	...	...	...	74·21	W. & S.	Could not divide.
372	49 Leonis...	1450	6·3, 9·5	10 28 44	9 16 14	156·0	6	2·54	3	·20	W. S. & Sm.	
373		1454	8, 10	10 31 30	27 13 59	310·9	5	...	...	·20	W. S. Sm.	
374		...	...	...	...	310·5	4	2·45	2	·22	W. & S.	Distance difficult and [underrated.
375		1457	7·3, 7·8	10 32 28	6 21 29	312·3	5	0·81	1	72·28	S.	
376		...	...	...	...	312·7	3	...	...	73·23	W. & S.	
377	172 B Ursæ Majoris	1460	8, 8	10 33 35	42 46 38	167·9	3	3·31	3	74·20	W. & S.	
378	... ...	...	...	...	...	166·3	5	3·12	3	·22	W. & S.	
379	AB	1474	7, 8, 8	10 41 43	−14 37 42	197·9	6	6·7	2	·17	W. S. Sm.	
380	...	...	...	...	...	196·6	4	6·8	2	·22	W. S.	
381	AC	...	...	...	...	203·4	2	...	...	·17	S.	
382	...	...	...	...	...	202·3	2	...	...	·22	W. & S.	
383		1476	7·5, 8·2	10 43 12	− 3 23 21	359·6	6	2·6	2	·20	W. S. Sm.	
384		...	...	...	...	358·8	9	2·23	3	·22	W. S. Sm.	
385		1478	8, 11	10 44 33	25 5 16	350·6	5	9·1	2	·20	W. S. Sm.	Extremely faint, night [dewy.
386		...	...	...	...	350·6	7	9·0	1	·22	W. S. Sm.	Distance W. only.
387		...	...	...	...	...	...	8·2	1	·22	S.	
388	54 Leonis	1487	5·7	10 49 7	25 23 24	105·4	4	6·3	2	73·24	W. & S.	Definition very good.
389	... ...	...	...	...	...	105·0	6	6·6	2	74·20	W. S. Sm.	Definition fair.
390		1496	8, 10	10 51 59	13 55 16	352·5	3	20·5	2	·22	W. & S.	
391		...	...	...	...	351·8	5	20·2	1	·22	W.	Three visitors assisted.
392		1500	7, 8	10 53 55	− 2 49 46	313·8	3	1·37	2	73·23	W. & S.	
393		...	...	...	...	315·4	5	1·39	2	·24	W. & S.	
394		...	...	...	...	314·1	1	...	...	74·22	W.	In haze, a mere guess.
395		1502	8½, 9	10 55 42	15 15 51	284·7	5	13·0	2	·22	W. & S.	Hazy.
396		...	...	...	...	283·5	3	12·9	2	·23	S. & Sm.	
397	P. X. 229 ...	1504	7½, 7½	10 57 48	4 17 6	284·5	7	1·19	1	·23	S. Sm.	Not clearly divided.
398	... ...	...	...	...	...	284·7	10	1·14	2	·24	W. F.	Satisfactory. Two nights.
399		1516	7, 7	11 7 26	74 7 24	269·1	4	7·6	4	72·30	S.	

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				h m s	° ′ ″	°		″				
400		1516	7, 7	11 7 26	74 7 24	269·0	5	7·8	2	73·25	W. & S.	
401	ξ Ursæ Majoris	1523	4, 5	11 11 48	32 12 45	43·9	4	1.1	...	71·48	{ W. S. A.M.W.	
402	... ...	...	...	...	...	23·1	7	1·04	1	72·13	W. & S.	
403	... ...	...	...	...	...	22·9	14	0·97	5	·17	W. & S.	
404	... ...	...	...	...	...	23·0	6	1·19	2	·20	W.	
405	... ...	...	...	...	...	23·3	4	0·91	2	·20	W. & S.	
406	... ...	...	...	...	...	20·3	3	...	...	·24	W.	Night watery, after rain.
407	... ...	...	...	...	...	19·7	4	1·18	2	·33	W.	
408	... ...	...	...	...	...	22·2	4	1·07	2	·38	S.	
409	... ...	...	...	...	...	3·9	23	0·90	8	73·22	W. & S.	Mean of five nights.
410	... ...	...	...	...	...	359·6	4	...	...	·36	W.	Not steady.
411	... ...	...	...	...	...	338·0	9	0·92	4	74·17	W. S. Sm.	Fair.
412	... ...	...	...	...	...	334·5	2	...	...	·23	W.	Definition as bad as [possible.
413	ν Ursæ Majoris	1524	4, 10	11 12 0	33 44 56	147·1	4	7·1	2	73·25	W.	
414	... ...	...	...	...	...	146·0	3	6·4	1	74·22	S.	
415	... ...	...	...	...	...	145·3	4	7·0	1	·23	S. & Sm.	
416	P. XI. 39	1530	8½, 9	11 13 40	− 6 14 31	313·5	3	7·9	2	73·25	W.	
417	... ...	...	...	...	...	313·4	4	7·4	4	74·22	W. & S.	
418		1534	8, 11	11 15 33	18 51 8	335·8	5	3·61	2	·23	W. & S.	Very bad definition.
419		...	...	...	...	333·6	5	...	...	·24	W. & S.	Difficult.
420	ι Leonis	1536	4·2, 8·5	11 17 39	11 11 31	70·3	5	3·2	2	72·27	S.	Very unsteady.
421	... ...	...	...	...	...	71·0	7	...	...	·35	W.	Bright star flaming.
422	... ...	...	...	...	...	70·1	4	2·57	2	73·19	W. & S.	
423	... ...	...	...	...	...	70·5	4	2·7	2	·23	W. & S.	
424	... ...	...	...	...	...	68·8	6	2·81	1	·25	W.	Very unsteady.
425	... ...	...	...	...	...	69·8	5	2·71	4	74·22	W. & S.	Difficult.
426	90 Leonis AB	1552	6, 7, 10	11 28 28	17 27 37	212·3	6	3·19	2	·23	S. & Sm.	Unsteady.
427	... ...	...	...	...	...	209·7	2	3·33	1	·23	W.	Very unsteady.
428	... ...	...	...	...	...	211·3	5	3·16	2	·24	W. & Sm.	

429	90 Leonis	AC	1552	6, 7, 10	11 28 28	17 27 37	235·0	...	...	...	74·23	S. & Sm.	
430	... ...	...	...	...	...	...	235·8	2	...	...	·23	W.	[tion.
431		AB	1558	9, 9, 9	11 30 26	22 8 8	...	...	...	...	·23	S. & Sm.	Not divided; bad defini-
432		AC	...	...	...	...	275·4	2	...	...	·23	S. & Sm.	Very unsteady.
433		...	...	...	...	...	277·0	2	...	...	·24	W.	In bright moonlight.
434			1594	9, 10	11 57 21	42 4 24	161·8	3	16·1	1	·23	S. & Sm.	Faint.
435			...	...	...	...	163·2	3	15·8	1	·24	W.	
436	2 Comæ Berenices		1596	6, 7	11 58 8	22 7 39	239·0	4	3·94	2	·23	S. & Sm.	
437	... ...		...	...	...	...	239·4	4	3·6	2	·24	W.	
438	2 Canum Venaticorum		1622	6, 8	12 10 7	41 19 43	260·3	4	11·5	2	·26	W. & S.	
439	... ...		...	...	...	...	259·0	7	11·5	2	·29	W. S. & Sm.	
440	17 Virginis		1636	6, 9	12 16 26	5 58 25	336·0	10	20·0	2	·26	W. S. L.	Definition very bad.
441	... ...		...	...	...	...	336·0	4	20·1	2	·29	W. & S.	
442			1646	8, 11	12 22 13	37 20 57	256·1	5	5	est.	·26	W. & S.	Definition very bad.
443			...	...	...	...	257·0	8	5·6	1	·29	W. S. & Sm.	Difficult; dist. a guess.
444	191 B Virginis		1647	7, 7·6	12 24 28	10 22 54	216·1	5	1·42	2	73·36	W. & Sm.	
445	... ...		...	...	...	...	214·2	6	1·15	3	74·29	W. S. Sm.	Definition very good.
446			1658	8, 10	12 29 0	8 6 30	352·0	8	1·97	3	·29	W. S. Sm.	Definition perfect.
447			...	...	...	...	352·4	5	2·18	2	·30	W. & S.	[moonlight.
448			1663	7·8, 8·7	12 31 11	21 51 35	100·3	3	0·8	est.	·31	W.	Through fleecy cloud;
449		AB	1664	8, 9, 11, 11	12 32 6	−10 51 26	252·7	4	...	...	·26	W.	
450		AC	...	...	...	...	304·1	2	...	...	·26	W.	
451		AD	...	...	...	...	292·0	2	...	...	·26	W.	
452		CD	...	...	...	...	276·2	2	...	...	·26	W.	
453		BC	...	...	...	...	325·7	2	...	...	·26	W.	
454	γ Virginis		1670	3, 3	12 35 36	− 0 47 29	160·1	6	5·30	4	71·37	W. S. A.M.W.	A first attempt.
455	... ...		...	...	...	...	159·2	6	5·40	3	·40	W. S. A.M.W.	
456	... ...		...	...	...	...	162·5	5	5·59	4	72·30	S.	
457	... ...		...	...	...	...	161·6	10	...	...	·33	W. S. & others	
458	... ...		...	...	...	...	162·6	8	...	...	·38	W.	
459	... ...		...	...	...	...	161·9	8	4·9	4	73·23	W. & S.	Very unsteady.
460	... ...		...	...	...	...	161·8	7	5·0	4	74·30	W. & S.	

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Dec. 1880.	Position-Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Observer.	Remarks.
				h m s	° ′ ″	°		″				
461	Virginis	1670	3, 3	12 35 36	− 0 47 29	160·4	6	5·02	3	74·31	W.	Through cloud; very [unsteady.
462		1678	6½, 7¼	12 39 25	15 1 49	202·0	4	32·2	2	73·35	S. & Sm.	
463		...	...	...	...	201·3	2	32·4	3	74·30	W. & S.	
464	35 Comæ Berenices AB	1687	6, 8, 8	12 47 23	21 53 52	57·0	5	1·28	2	73·24	W. & S.	
465	... ...	...	...	...	...	58·7	6	1·33	2	·35	S. & Sm.	
466	... ...	...	...	...	...	59·1	4	...	...	74·26	Sm.	
467	... ...	...	...	...	...	56·8	5	1·44	3	·30	W. & S. Sm.	
468	... ... AC	...	...	...	...	125·7	2	...	...	73·24	W. & S.	
469	... ...	...	...	...	...	125·5	1	...	...	74·26	Sm.	
470	44 Virginis	1704	6, 11	12 53 29	− 3 9 52	52·8	4	...	...	·30	W. & S.	
471	... ...	...	...	...	...	53·0	3	21·9	...	·30	W. & S.	
472		1712	9, 9	12 57 46	10 6 5	332·5	5	8·7	2	·30	W. S. Sm.	Difficult.
473		...	...	...	...	331·4	5	8·0	2	·30	W. S.	Distance very difficult.
474	427 B Virginis AB	1716	8, 11, 12, 12	12 58 28	9 17 48	149·0	10	2·4	4	·30	W. & S. Sm.	Several other companions.
475	... ... AC	...	...	...	...	232·6	1	30·0	est.	·30	W.	
476	... ... AD	...	...	...	...	20·8	1	30·0	est.	·30	W.	
477	179 B Comæ Berenices	1722	8, 9	13 2 30	16 8 6	335·0	2	...	...	·26	Sm.	Shaky.
478	... ...	...	...	...	...	339·8	5	...	...	·30	W. & S.	Very unfavourable.
479	... ...	...	...	...	...	...	...	3·41	2	·30	W.	
480	... ...	...	...	...	...	...	...	3·07	2	·30	S.	
481	... ...	...	...	...	...	341·5	4	3·09	...	·41	W.	Difficult.
482	θ Virginis AB	1724	4, 9, 9	13 3 44	− 4 53 52	343·9	5	6·9	2	·32	W.	
483	... ...	...	...	...	...	343·9	6	7·0	2	·32	W. Sm. L.	
484	... ... AC	...	...	...	...	298·1	2	28·0	est.	·32	W.	Unsteady.
485	... ...	...	...	...	...	296·6	4	...	...	·32	W. & Sm.	Better.
486	42 Comæ Berenices	1728	5·5, 5·7	13 4 10	18 9 46	...	...	...	...	73·36	W.	Examined; round.
487		1734	7, 8	13 14 36	3 34 23	190·1	6	1·11	3	74·32	W.	Very unsteady.
488		...	...	...	...	192·5	8	1·02	3	·32	W. & Sm.	Better.

489		1742	7, 8	13 18 11	2 1 37	352·9	2	1·10	1	74·32	W.	Night not good enough.
490		...	...	...	...	351·0	8	1·16	2	·32	W. & Sm.	Better.
491	ζ Ursæ Majoris	1744	2¼, 4	13 19 5	55 33 9	148·8	3	14·5	2	73·25	W. & S.	
492	... ...	...	...	...	...	147·2	4	14·5	2	·30	S.	With Barlow lens.
493		1746	8, 10	13 22 10	10 5 2	346·1	7	15·1	2	74·32	W. & Sm.	Difficult. Is this Σ 1746?
494	P. XIII. 127	1757	7·5, 8·2	13 28 10	0 18 3	64·8	8	2·30	4	72·33	W. & S.	
495	... ...	...	...	...	...	64·0	5	2·05	3	73·23	W. & S.	Fairly good.
496	... ...	...	...	...	...	65·0	5	2·00	2	·35	S.	
497	... ...	...	...	...	...	65·5	7	2·15	2	74·32	W. & G.	Hazy night.
498	... ...	...	...	...	...	65·9	4	...	...	·32	W.	Very bad definition; [readings wild.
499	... ...	...	...	...	...	64·2	5	2·16	2	·41	W. & S.	
500		1758	8, 8	13 27 55	49 45 26	310·0	5	3·91	2	·44	W. S. G.	
501	181 B Can. Venat.	1768	5·7, 7·6	13 32 8	36 54 18	...	...	...	...	72·38	W.	Round; night very good.
502	84 Virginis	1777	6, 8	13 37 3	4 8 47	230·9	4	3·66	2	73·34	W.	
503	... ...	...	...	...	...	231·2	4	3·33	2	·36	W. & S.	
504	... ...	...	...	...	...	232·5	3	3·22	...	74·32	W. & Sm.	
505		1781	7·8, 8·2	13 40 5	5 43 7	257·5	4	0·95	2	72·38	W. & S.	
506		...	...	...	...	256·4	5	1·20	2	73·23	W. & S.	Fairly good.
507		...	...	...	...	261·4	5	1·23	2	·34	W.	Hazy.
508		...	...	...	...	260·7	4	1·02	2	·35	S.	
509		...	...	...	...	256·0	8	1·23	1	74·23	W. & Sm.	Very bad; readings wild.
510		...	...	...	...	256·5	9	1·3	3	·32	W. & Sm.	
511	τ Boötis ...	[270]	4½, 11¼	13 41 34	18 2 57	349·9	7	...	...	73·36	W. & S.	Bears illumination; [readings differ.
512		1785	7, 7·4	13 43 38	27 34 52	200·2	5	2·47	2	72·38	S.	
513		...	...	...	...	203·2	4	2·47	2	73·23	W. & S.	Fairly good.
514		...	...	...	...	201·0	4	2·46	2	·35	W. & S.	Good.
515		...	...	...	...	204·5	9	2·41	5	74·32	W.	
516	P. XIII. 238	1788	6·5, 7·4	13 48 41	− 7 28 4	70·2	3	2·59	2	73·23	W. & S.	
517	... ...	...	...	...	...	70·7	7	2·66	3	·35	W. & S.	
518	... ...	...	...	...	...	69·3	8	2·67	2	74·32	W. & Sm.	
519		1796	9, 10	13 55 16	37 33 1	193·3	5	2·4	est.	·32	W. & Sm.	
520	76 B Boötis	1804	8, 9	14 2 39	21 45 56	19·6	4	4·6	2	73·35	W. & S.	

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				h m s	° ′ ″	°		″				
521	76 B Boötis	1804	8, 9	14 2 39	21 45 56	19·9	6	4·20	3	74·32	W. & Sm.	Bad definition.
522		1806	9, 10	14 4 13	49 4 25	...	...	...	...	·42	W.	Failed.
523		1813	8, 8	14 7 24	5 57 48	193·1	4	5·0	2	73·36	W. & S.	
524		1816	7, 7	14 8 34	29 40 1	...	...	1·67	2	·36	W. S.	Night bad; position too [doubtful.
525		...	...	...	...	79·6	4	1·44	2	74·32	W. Sm.	Satisfactory.
526		1819	8, 8	14 9 18	3 41 18	23·9	8	1·25	3	72·38	W. & S.	Doubtful measures.
527		...	...	...	...	25·7	10	1·13	4	·39	W. & S.	
528		...	...	...	...	27·4	3	1·17	2	73·23	W. & S.	
529		...	...	...	...	25·0	4	1·35	2	·36	W. & S.	Satisfactory.
530		...	...	...	...	23·5	6	1·33	2	·36	W. & S.	
531		...	...	...	...	23·2	6	1·33	1	74·41	W. S. & Sm.	
532	121 B Boötis	1825	8½, 9½	14 10 59	20 40 59	179·8	6	4·0	3	72·38	W. & S.	
533	... ...	...	...	...	...	179·7	4	4·0	2	·41	S.	B looks like 8½.
534	... ...	...	...	...	...	178·0	4	4·1	2	73·36	W. & S.	
535	... ...	...	...	...	...	177·5	5	3·93	4	74·93	W. & G.	Very good definition.
536		1830	8½, 9	14 11 52	57 13 48	283·9	4	5·5	2	73·25	W. & S.	
537		...	...	...	...	285·9	4	...	...	·29	S.	Night very hazy.
538	ι Boötis ...		7, 7	14 11 56	51 55 9	34·3	3	...	...	·25	W. & S.	$\frac{A+B}{2}$, C
539	... ...		...	...	...	33·4	4	...	...	74·42	W.	Fancied AB elongated [in direction 55°.
540		1831	6, 8	14 12 17	57 16 9	141·2	4	6·5	3	73·25	W. & S.	
541		...	...	...	...	140·3	4	5·6	3	·29	S.	
542		1832	8, 8	14 12 51	4 26 51	...	...	...	...	74·41	W.	Failed; very close.
543		1834	7, 7	14 15 54	49 3 26	113·7	11	0·6	est.	·42	W. & S.	Three nights.
544	P. XIV. 70	1837	7, 9	14 18 14	−11 7 26	311·6	5	1·33	2	73·36	W. & S.	Estimated at 6, 8½.
545		1842	9, 9	14 20 57	4 13 51	14·5	6	2·8	2	74·41	W. S. Sm.	
546		...	...	...	...	14·5	7	2·71	2	·42	W. Sm.	
547	φ Virginis	1846	5, 10	14 22 2	− 1 41 23	115·7	11	3·77	2	·41	W. S. Sm.	Position uncertain; bears [illumination well.
548	... ...	...	...	...	...	120·6	4	4·12	3	·42	W.	Def. very imperfect.

549		1850	6, 7	14 23 16	28 49 36	262·3	2	...	...	74·41	W. & S.	
550		...	...	...	...	262·6	3	25·8	2	·42	W.	
551		1863	7, 7	14 34 1	52 5 47	99·5	4	0·6	2	72·41	S.	Very close; not clearly [divided.
552		...	...	...	...	89·5	4	0·6	est.	73·25	W. & S.	Bad readings.
553		...	...	...	...	94·3	4	0·57	1	·30	S.	With Barlow.
554		...	...	...	...	94·1	2	0·65	est.	·36	W.	
555	ζ Boötis ...	1865	3½, 4	14 35 25	14 14 36	298·9	3	...	...	71·50	W.	
556	... ...	...	...	...	...	301·6	10	0·93	5	72·38	W. & S.	
557	... ...	...	...	...	...	300·2	5	0·88	2	73·36	W. & S.	
558	... ...	...	...	...	...	302·2	7	0·92	3	74·41	W. & S.	
559	... ...	...	...	...	...	301·0	6	0·98	2	·42	W. S. Sm.	Definition good.
560		1866	8, 8	14 35 54	10 2 23	23·5	6	0·93	2	·42	W. & Sm.	
561	260 B Boötis	1867	8, 8	14 35 39	31 48 27	16·6	5	1·30	2	73·36	W. & S.	Cloud coming on; very [difficult.
562	... ...	...	...	...	...	17·5	7	1·37	2	74·42	W. & Sm.	
563		1870	8, 11	14 37 1	8 35 14	...	...	...	...	·42	W. & Sm.	Failed to see B.
564		1876	8, 8	14 40 1	− 6 52 48	68·6	7	1·17	4	72·38	W. & S.	
565		...	...	...	...	69·7	7	1·27	2	73·36	W.	
566	ε Boötis ...	1877	3, 7	14 39 45	27 34 47	327·2	4	2·97	4	71·56	S.	
567	... ...	...	...	...	...	326·9	3	3·06	4	72·38	W. & S.	Stars tremulous.
568	... ...	...	...	...	...	326·9	5	3·00	2	73·36	W. & S.	Stars blazing.
569	... ...	...	...	...	...	327·6	6	3·00	4	74·42	W.	
570	... ...	...	...	...	...	326·1	8	2·9	3	·44	W. S. G.	Stars blazing.
571		1883	7, 7	14 42 56	6 27 29	261·7	5	0·88	2	72·37	S. & M.	
572		...	...	...	...	261·9	3	0·95	2	73·36	W. & S.	
573	286 B Boötis	1884	6, 8	14 43 4	24 51 53	56·3	2	1·23	2	·36	W. & S.	
574	... ...	...	...	...	...	55·2	6	1·30	2	74·44	W. & Sm.	Bad definition.
575	ξ Boötis ...	1888	3½, 6½	14 45 51	19 35 57	291·8	5	4·1	4	72·38	W. & M.	Bad definition.
576	... ...	...	...	...	...	289·3	5	4·88	2	73·36	W. & S.	
577	... ...	...	...	...	...	289·4	5	4·81	2	·38	W.	
578	... ...	...	...	...	...	288·4	5	4·72	2	74·44	W. & Sm.	Definition bad.
579	39 Boötis...	1890	6, 7	14 45 37	49 12 44	45·8	3	3·87	2	73·25	W. & S.	
580	... ...	...	...	...	...	45·8	4	3·64	1	·30	S.	With Barlow lens.

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				h m s	° ′ ″	°		″				
581		[288]	6, 8	14 47 47	16 11 21	197·8	6	1·16	2	73·37	W. & S.	Definition bad.
582		...	...	...	...	196·5	4	1·55	2	·44	W.	Definition bad.
583		...	...	...	...	198·2	4	1·26	2	74·44	W. & Sm.	A probable binary.
584	18 Libræ ...	1894	6, 10	14 52 24	−10 39 37	39·6	5	20·1	2	·44	W. & Sm.	
585	44 Boötis...	1909	5, 6	14 59 52	48 7 15	239·8	4	5·3	4	71·57	S.	
586	... ...	...	...	...	...	240·6	4	5·3	3	73·25	W. & S.	
587	AB	1908	8, 9, 12	15 0 6	34 55 58	144·6	6	1·3	est.	74·44	W. S. Sm.	
588	...	...	...	...	...	143·0	6	1·23	1	·50	W. H. L.	
589	AC	...	...	...	...	102·7	1	40·0	est.	·44	W.	
590	...	...	...	...	...	98·7	1	...	...	·50	W.	
591	P. XIV. 279	1910	7, 7	15 1 46	9 41 11	211·4	4	4·3	3	·44	W. & Sm.	
592		1931	6·2, 7·6	15 13 10	2 13 35	171·1	3	13·2	3	73·37	W. & S.	
593		...	...	...	...	171·0	3	13·2	1	·45	W.	
594	1 B Coronæ	1932	6, 6½	15 13 12	27 16 29	296·3	7	1·02	3	72·49	W. & S.	
595	... ...	...	...	...	...	296·8	5	1·21	2	73·36	W. & S.	
596	... ...	...	...	...	...	298·6	6	1·07	3	74·44	W. S. Sm.	
597	... ...	...	...	...	...	299·4	6	1·1	est.	·49	W. Sm.	
598		1934	8½, 8½	15 13 10	44 14 5	35·9	4	6·2	2	73·25	W. & S.	
599		...	...	...	...	34·7	5	5·8	2	·33	W. & S.	
600		...	...	...	...	35·5	6	6·2	4	74·43	W. & S.	Night unfavourable.
601	η Coronæ...	1937	6, 6½	15 18 14	30 43 25	45·2	5	1·47	3	71·55	S.	
602	... ...	...	...	...	...	50·0	4	1·38	4	·57	S.	
603	... ...	...	...	...	...	51·0	7	1·01	4	72·49	W. S. M.	
604	... ...	...	...	...	...	58·0	5	1·01	2	73·36	W. & S.	
605	... ...	...	...	...	...	57·6	3	1·22	2	·38	W. & S.	
606	... ...	...	...	...	...	55·6	5	1·09	2	·45	W. & S.	Pretty good readings.
607	... ...	...	...	...	...	58·4	8	0·93	3	74·44	W. S. Sm.	
608	... ...	...	...	...	...	58·1	6	...	...	·49	W. Sm.	

609	μ^2 Boötis			1938	8, 8½	15 19 59	37 45 59	167·9	4	0·70	2	71·57	[illegible]	[our power.
610	...	...		...	...	...	...	164·5	1	0·4	est.	72·33	W.	Only elongated; beyond
611	...	...		...	...	...	...	162·3	3	0·3	est.	·38	W. & S.	Separated, but doubtful.
612	...	...		...	...	...	...	151·0	4	0·45	est.	73·25	W. & S.	Separated at intervals.
613	...	...		...	...	...	...	152·0	3	...	...	·33	W. & S.	
614	...	...		...	...	...	...	150·1	7	0·6	est.	·44	W.	Definition bad; readings [wild.
615	...	...		...	...	...	...	149·1	7	0·7	4	74·44	W. S. Sm.	Definition good.
616				[296]	7½, 9	15 22 10	44 26 36	316·0	6	1·47	2	73·37	W. & S.	Definition bad and eyes [tired.
617				...	...	...	...	316·9	2	1·61	2	·44	W.	
618				...	...	...	...	316·8	5	1·33	1	74·50	W. & Sm.	[hazy.
619	17 B Coronæ			1950	7, 8	15 24 50	25 55 14	92·0	8	3·26	3	73·39	W. S. M.	Stars tremulous and
620	δ Serpentis			1954	3, 5	15 29 4	10 56 23	192·1	5	3·56	4	71·56	S.	
621	...	...		...	...	...	...	191·5	5	3·51	2	73·36	W. S.	
622	...	...		...	...	...	...	192·9	4	3·1	3	74·50	W. & H.	
623	...	..		...	...	...	...	191·0	2	3·23	1	·50	Sm.	
624				1957	8, 9½	15 30 13	13 18 52	155·9	6	1·11	3	73·37	W. & S.	Definition very bad.
625				...	...	...	...	154·3	4	1·38	2	·39	W. & S.	Definition very bad.
626				...	...	...	...	152·0	3	1·5	est.	74·50	W. & Sm.	
627				[298]	7½, 7¾	15 31 37	40 13 0	187·3	2	0·7	est.	·50	W.	
628				...	...	...	...	190·9	2	0·5	est.	·50	Sm.	
629	ζ Coronæ			1965	4, 6½	15 34 52	37 1 31	302·7	8	6·23	3	73·37	W. S. L.	Very bad definition.
630	...	...		...	...	...	...	301·1	4	...	...	·40	W.	Satisfactory.
631	...	...		...	...	...	...	299·9	2	...	...	·40	Sm.	
632	γ Coronæ Borealis			1967	4, 6½	15 37 43	26 40 31	...	...	...	...	72·45	W. & S.	If anything, 190°
633	...	...		...	...	...	...	...	...	...	...	73·36	W. & S.	If anything, 195°
634	...	...		...	...	...	...	...	...	...	...	·40	W.	Failed entirely.
635	ξ Libræ ...		AB	1998	4½, 5, 6½	15 57 46	−11 2 31	177·3	6	0·95	2	72·45	W. & S.	
636	...	...	...	...	...	...	...	180·4	4	1·04	2	73·36	W. & S.	
637	...	...	...	...	...	...	...	183·1	4	1·19	1	74·44	W. & Sm.	
638	...	...	AC	...	...	...	...	72·0	6	6·91	2	72·45	W. & S.	
639	...	...	...	...	...	...	...	71·7	3	6·7	3	73·36	W. & S.	
640	49 Serpentis			2021	7, 7½	16 7 42	13 51 10	327·7	6	3·73	3	72·45	W. & S.	

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				h m s	° ′ ″	°		″				
641	49 Serpentis	2021	7, 7½	16 7 42	13 51 10	328·2	4	3·85	2	73·37	W. & S.	Definition poor.
642		2026	8½, 9½	16 8 54	7 40 0	318·9	4	1·4	2	72·45	W. & S.	Very delicate.
643		...	...	...	...	315·6	3	1·51	1	73·45	W.	Mist coming on.
644		...	...	...	...	315·7	6	...	...	·46	W. & Sm.	
645	σ Coronæ... AB	2032	6, 6½, 11	16 10 12	34 9 48	194·3	3	3·51	2	71·51	W.	
646	... ...	...	...	...	...	197·7	8	3·25	4	72·53	W. & M.	
647	... ...	...	...	...	...	198·4	5	3·14	1	73 42	W.	
648	... ... AC	...	...	...	...	88·2	1	52·6	2	71·51	W.	
649	... ...	...	...	...	...	88·2	8	..	...	72·53	W. & M.	
650	... ...	...	...	...	...	87·9	5	...	...	73·42	W. & Sm.	
651	υ Coronæ Borealis AB		6, 10, 9, 13	16 11 56	29 26 50	22·4	2	...	...	72·53	W.	
652	... ...		...	...	...	22·3	3	...	...	73·48	W. & S.	
653	... ... AC		...	...	...	52·8	2	...	...	72·53	W.	
654	... ...		...	...	...	52·3	3	...	...	73·48	W. & S.	
655	... ... CB		...	...	...	275·6	1	...	...	72·53	W.	
656	... ... BD		...	...	...	221·9	5	...	...	·53	W. & M.	D very faint.
657	... ...		...	...	...	222·0	3	...	...	73·48	W. & S.	
658	α Scorpii ...		1, 8	16 22 3	−26 9 54	268·7	4	3·41	2	·42	W.	[nation well.
659	η Draconis	[312]	2·3, 8	16 22 21	61 47 5	142·5	3	4·90	1	·42	W. & Sm.	Small star bears illumi-
660		2051	7, 9	16 23 44	10 51 22	19·2	3	13 76	2	·42	W.	
661	71 B Herculis	2052	7·5, 7·5	16 23 37	18 39 34	103·1	6	2·74	3	74·55	W. & S.	Fair night.
662	... ...	...	...	...	...	103·5	4	2·53	2	·62	S.	Night good.
663	λ Ophiuchi	2055	4, 6	16 24 52	2 14 52	28·9	5	1·56	3	72·45	W. & S.	
664	... ...	...	...	...	...	30·3	8	1·62	2	73·42	W.	
665	... ...	...	...	...	...	33·6	4	1·31	2	74·62	S.	
666		2072	8½, 9½	16 32 9	47 55 38	183·1	3	...	...	·55	W. & S.	
667		...	...	...	...	182·5	4	4·9	2	·62	S.	
668		2076	9, 10	16 34 32	0 5 50	325·1	3	8·68	2	·55	W. & S.	
669	ζ Herculis	2084	3, 6	16 36 48	31 48 52	165·4	3	1·2	est.	73·45	W.	

670	ζ Herculis		2084	3, 6	16 36 48	31 48 52	166·8	3	...	...	73·46	W.	
671	... ...		...	...	...	...	168·0	8	0·76	2	·47	W. S. H.	Good def.; ? distance.
672	... ...		...	...	...	...	153·5	4	1·06	2	74·55	W. & S.	
673	... ...		...	...	...	...	159·3	4	1·1	2	·62	S.	
674	η Herculis		2093	3, 10	16 38 47	39 9 6	261·4	3	113·7	3	73·47	W. & S.	Small star bears illumination badly.
675	... ...		...	...	...	...	260·8	1	115·0	2	·48	W.	
676	... ...		...	...	...	...	261·6	2	114·3	2	74·55	W. & S.	
677	46 Herculis		2095	7, 9	16 40 19	28 34 35	163·8	4	5·1	2	73·47	W. & S.	
678	21 Ophiuchi			6½, 8	16 45 20	1 25 15	167·9	3	1·4	est.	·46	W.	B estimated at 9th mag.
679	... ...			...	...	...	165·2	9	1·13	2	·48	W. H. Sm.	Night good.
680			2106	6, 8	16 45 24	9 36 54	310·7	3	0·5	est.	·45	W. & S.	Very difficult.
681			...	...	...	...	306·6	3	...	...	·46	W.	Never divided.
682			...	...	...	...	311·9	6	0·6	est.	·46	W. & Sm.	Not divided.
683	167 B Herculis		2107	6½, 8½	16 47 5	28 51 59	210·0	5	0·77	1	72·49	W. & S.	
684	... ...		...	...	...	...	207·5	6	0·7	est.	73·48	W.H. & Sm.	Fairly good.
685	... ...		...	...	...	...	208·4	3	0·7	est.	74·65	S.	
686		AB	3107	8·5, 8·5	16 52 45	4 11 36	106·0	10	1·5	est.	73·46	W. & Sm.	Not satisfactory.
687		...	...	...	...	...	103·5	4	1·50	2	·48	W. & Sm.	Definition very good.
688		AC	...	...	...	...	41·3	2	...	...	·46	W.	
689	P. XVI. 270		2114	7, 8	16 56 13	8 37 30	151·9	9	1·6	est.	·46	W. & Sm.	
690	... ...		...	...	...	...	152·2	6	1·39	2	·47	W. H. Sm.	Satisfactory.
691	... ...		...	...	...	...	151·7	4	0·9	2	74·62	S.	
692	19 Draconis		2118	6, 7	16 55 20	65 19 2	...	...	...	...	73·50	W. & S.	Failed.
693	... ...		...	...	...	...	303·2	2	0·4	est.	74·70	W. & S.	
694	210 B Herculis		2120	6½, 9	17 0 0	28 15 20	262·9	4	3·78	2	72·48	W.	
695	... ...		...	...	...	...	261·7	6	3·65	2	73·50	W. S. Sm.	Is the companion a [variable?
696	... ...		...	...	...	...	258·5	4	4·2	2	74·62	S.	
697	μ Draconis		2130	4, 4½	17 2 51	54 37 38	177·5	4	2·44	4	71·56	S.	
698	... ...		...	...	...	...	174·0	8	2·7	3	72·50	W. S. M.	In haze.
699	... ...		...	...	...	...	174·4	4	2·5	2	·78	S.	Very good definition.
700	... ...		...	...	...	...	173·7	4	2·8	3	73·50	W. & S.	
701	... ...		...	...	...	...	172·3	4	2·85	1	74·62	S.	
702	36 Ophiuchi			4½, 6½	17 7 59	−26 25 30	204·2	4	4·6	2	72·51	S.	Dist. very unsatisfactory.

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Dec. 1880.	Position-Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Observer.	Remarks.
				h m s	° ′ ″	°		″				
703	36 Ophiuchi		4½, 6½	17 7 59	−26 25 30	204·5	4	...	...	72·52	W.	Magnitudes nearly equal, and stars elongated into [spectra.
704	... ...		...	...	...	204·1	2	...	...	·53	M.	
705	α Herculis	2140	3, 6	17 9 11	14 31 36	115·1	6	...	...	71·52	W. & S.	
706	... ...	...	...	...	...	115·0	6	4·77	3	72·51	W. & S.	
707	... ...	...	...	...	...	116·1	6	4·63	3	·52	W. & M.	
708	... ...	...	...	...	...	115·1	7	...	...	·54	W. S. M.	
709	... ...	...	...	...	...	115·7	5	4·65	2	73·48	W. H.	
710	... ...	...	...	...	...	115·0	5	...	...	74·62	S.	
711	δ Herculis	3127	4, 8½	17 10 6	24 58 58	181·2	6	20·0	4	71·48	{ W. S. A.M.W.	
712	... ...	...	...	...	...	180·1	7	19·3	3	72·48	W. M.	Low power.
713	... ...	...	...	...	...	181·2	4	19·2	2	·52	S.	
714	... ...	...	...	...	...	181·5	10	19·3	2	·53	W. & M.	Satisfactory.
715	... ...	...	...	...	...	181·7	3	18·8	3	73·50	W. & S.	Satisfactory.
716		2156	8, 9	17 17 47	− 0 43 22	35·9	5	...	...	74·54	W. C. H. W.	Def. very imperfect.
717		...	...	...	...	34·2	7	3·22	4	·57	W. & S.	Better readings.
718		...	...	...	...	36·0	5	3·40	2	·63	S.	
719	P. XVII. 94	2160	5½, 10	17 19 9	15 42 54	65·6	8	4·05	4	73·50	W. & S.	Two nights.
720	... ...	...	...	...	...	65·9	8	3·85	2	·51	W. S. H.	
721	ρ Herculis	2161	4, 5½	17 19 33	37 15 22	311·3	4	4·28	4	71·52	W. & S.	
722	... ...	...	...	...	...	311·9	3	4·48	1	·53	W.	
723	... ...	...	...	...	...	311·6	4	3·96	2	72·51	W.	
724	... ...	...	...	...	...	311·2	6	4·04	4	·52	W. & M.	
725	... ...	...	...	...	...	312·7	4	4·17	2	·52	S.	
726	... ...	...	...	...	...	311·7	10	...	...	73·46	W. S. & others	
727	... ...	...	...	...	...	311·9	4	3·8	2	·63	S.	
728	281 B Herculis	2165	7, 8½	17 21 35	29 33 33	51·5	4	...	...	72·49	W.	B very faint.
729	... ...	...	...	...	...	51·5	4	7·7	2	73·50	W. & S.	
730	... ...	...	...	...	...	53·7	4	7·6	2	74·63	S.	

731			2173	6, 7	17 24 14	− 0 57 39	334·1	7	1·10	3	73·50	W. S. Sm.	Unsatisfactory; defini- [tion very bad.
732			...	...	...	...	334·0	9	0·91	1	·51	W.S.H.Sm.	
733			...	...	...	...	331·6	6	0·90	2	74·55	W. & S.	
734			...	...	...	...	330·9	4	...	...	·63	S.	
735	P. XVII. 147		2180	7, 7	17 26 5	50 57 47	264·1	5	3·10	3	73·51	W. S. H.	Satisfactory.
736	... ...		...	...	...	...	264·8	4	2·90	2	74·70	W. & S.	
737	53 Ophiuchi			5·8, 8	17 28 55	9 40 4	191·7	4	40·7	3	73·47	W. & S.	Low power used.
738	315 B Herculis		2192	7½, 10	17 35 24	29 18 14	71·6	4	10·2	2	74·55	W. & S.	
739	... ...		...	...	...	...	73·2	4	10·6	2	·63	S.	
740	P. XVII. 200		2194	6½, 9	17 36 10	24 34 17	9·2	2	15·0	1	73·50	S.	
741	... ...		...	...	...	...	9·8	4	16·3	2	74·63	S.	
742			2199	7, 8	17 36 24	55 49 29	99·6	10	1·51	4	72·50	W. S. M.	Measures bad. [both.
743			...	...	...	...	98·4	8	1·54	4	73·33	W. & S.	Do.; W. & S. differed in
744			...	...	...	...	100·7	7	1·44	3	74·70	W. & S.	Not satisfactory measures.
745	61 Ophiuchi		2202	5½, 6	17 38 33	2 37 51	93·1	5	20·7	4	·54	{ W. S. C. H. W.	
746	... ...		...	...	...	...	93·4	3	20·5	2	·55	W. & S.	
747	μ Herculis	AB	2220	5, 10, 10	17 41 47	27 48 4	244·8	3	31·2	3	71·51	{ W. S. A.M.W.	
748	... ...	...	...	...	...	...	245·2	2	31·0	2	73·50	W. & S.	
749	... ...	BC	...	...	...	...	100·0	est.	0·6	est.	71·51	W.&C.P.R.	Very close.
750	... ...	...	...	...	...	...	90·0	est.	0·6	est.	73·50	W. & S.	
751	337 B Herculis		2224	7, 10	17 42 1	39 22 4	351·4	3	...	...	74·54	W. & S.	Difficult.
752	... ...		...	...	...	...	349·1	4	6·5	2	·55	W. & S.	Ditto.
753	... ...		...	...	...	...	351·1	4	7·6	2	·63	S.	
754			2234	9, 9	17 46 17	− 7 56 31	...	...	...	...	·57	W. & S.	Failed; three hours from [meridian.
755			...	...	...	...	200·3	4	16·2	2	·63	S.	
756			2240	9, 10	17 47 40	5 17 19	...	...	...	...	·63	S.	Failed.
757	A. C. 8			8·2, 8·2	17 48 45	29 42 9	244·0	5	0·35	est.	73·51	W. & S.	Fairly good.
758	...			...	...	...	...	...	...	...	74·70	W. & S.	Failed.
759	P. XVII. 300		2245	7, 7	17 51 8	18 20 40	296·5	4	2·68	2	73·50	S.	
760	... ...		...	...	...	...	297·1	5	2·64	3	74·57	{ W.S. & S.G.T.	Distance measures good.
761	... ...		...	...	...	...	296·3	6	...	...	·63	S.	
762			2252	8, 8	17 52 58	2 2 54	26·5	2	3·97	1	·54	S.	
763			...	...	...	...	25·4	4	3·83	2	·63	S.	

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1800.	Dec. 1880.	Position-Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Observer.	Remarks.
				h m s	° ′ ″	°		″				
764		2254	8, 9	17 53 27	12 26 56	266·5	6	3·47	2	73·51	W. S. H.	Distance unsatisfactory.
765		...	...	...	...	267·6	4	3·11	2	74·63	S.	
766		2258	8½, 8½	17 53 35	48 38 6	221·7	4	2·6	2	·63	S.	
767		...	...	...	...	222·2	4	2·06	2	·70	W. & S.	Very hazy.
768	τ Ophiuchi	2262	5, 6	17 56 33	− 8 10 46	248·9	4	1·67	2	72·49	W.	
769	... ...	...	...	...	...	250·3	4	1·70	2	·52	W.	
770	... ...	...	...	...	...	250·8	10	1·71	3	73·52	W. S. H.	
771	... ...	...	...	...	...	249·4	4	1·64	2	74·63	S.	
772	95 Herculis	2264	5, 5	17 56 25	21 35 46	261·4	5	6·5	5	71·53	W.	
773	... ...	...	...	...	...	261·7	3	5·4	4	·54	W. & C.P.R.	
774	... ...	...	...	...	...	261·9	7	6·2	2	73·52	W.S.H. Sm.	
775	... ...	...	...	...	...	261·6	4	6·3	3	74·87	S.	
776		2268	8, 9	17 58 19	25 21 39	215·1	5	18·0	4	·68	W. & S.	Two nights.
777	70 p Ophiuchi	2272	4½, 7	17 59 23	2 32 35	92·8	3	4·6	3	71·48	W.S. A.M.W.	
778	... ...	...	...	...	...	92·5	4	4·60	2	·49	W. A.M.W.	
779	... ...	...	...	...	...	...	...	4·61	2	72·49	W.	Zero shifted.
780	... ...	...	...	...	...	90·7	9	4·32	3	·50	W. S. M.	
781	... ...	...	...	...	...	91·9	4	4·17	4	·52	W. S.	
782	... ...	...	...	...	...	91·8	6	4·07	3	·54	W. M.	
783	... ...	...	...	...	...	88·8	5	4·1	3	73·51	W. S. H.	
784	... ...	...	...	...	...	88·5	4	3·93	2	·63	S.	
785	P. XVII. 362	2276	8, 8½	18 0 8	11 59 38	258·8	3	6·8	3	73·51	W. S. H.	
786	... ...	...	...	...	...	259·0	4	6·6	2	74·64	S.	
787	... ...	...	...	...	...	258·7	4	6·5	2	·72	W. S. G.	
788	72 Ophiuchi	[342]	6, 7	18 1 39	9 33 0	...	...	...	...	73·51	W.	Round.
789	100 Herculis	2280	7, 7	18 2 59	26 4 44	182·6	8	14·0	2	·52	W. S. Sm.	
790	73 Ophiuchi	2281	6, 7½	18 3 36	3 58 22	252·8	6	1·45	3	71·50	W. S.	
791	... ...	...	...	...	...	253·7	4	1·37	2	72·54	W.	
792	... ...	...	...	...	...	253·6	3	...	...	·54	M.	

793	73 Ophiuchi		2281	6, 7½	18 3 36	3 58 22	255·9	6	1·35	2	72·55	W.	In cloud; measures bad.
794	... ...		...	...	...	...	255·6	3	1·29	2	73·53	W.	
795	... ...		...	...	...	...	254·2	4	1·06	2	74·64	S.	
796	417 B Herculis		2289	6½, 7½	18 4 47	16 27 14	235·7	4	·97	2	72·50	S.	Difficult and unsatisfac- [tory.
797	... ...		...	...	...	...	236·3	5	1·25	2	·50	W.	
798	... ...		...	...	...	...	235·8	7	1·03	3	73·54	W. S. H.	
799	... ...		...	...	...	...	238·1	5	1·14	2	74·64	S.	
800	μ^1 Sagittarii	AD		3½, 16, 9½, 10	18 6 31	−21 5 33	116·0	4	...	...	73·54	W. & S.	B not seen.
801	... ...	AC		...	...	...	311·6	4	48·9	1	·54	W. & S.	
802			2298	8½, 8½	18 8 51	41 21 8	179·5	6	2·57	2	74·64	S.	
803			...	...	...	...	179·4	2	2·0	1	·70	W.	In cloud; valueless.
804			...	...	...	...	177·2	4	...	...	·72	W. & S.	Very bad definition; [measures bad.
805			...	...	...	...	177·5	3	...	...	·72	Sm.	
806			...	...	...	...	182·4	4	2·14	2	·72	S.	
807			2310	7, 10	18 15 37	22 44 39	238·1	4	5·1	2	·64	S.	
808	21 Sagittarii	AC 10		5, 8·2	18 18 11	−20 36 9	...	...	...	...	73·54	W. & S.	Quite uncertain.
809	... ...	...		...	...	...	...	...	...	...	·54	W. & H.	B not seen.
810	59 Serpentis		2316	6, 7½	18 21 4	0 7 28	316·2	11	4·5	5	71·53	W. S. K.	
811	... ...		...	...	...	...	316·9	4	3·9	2	72·54	W.	
812	... ...		...	...	...	...	315·6	6	4·18	2	73·54	W. S. H.	
813	... ...		...	...	...	...	315·8	4	3·75	2	74·64	S.	
814	39 Draconis	AB	2323	5, 8½, 7	18 22 10	58 43 49	1·2	3	...	...	73·55	W. & S.	Definition worst possible.
815	... ...	...	...	...	...	...	0·7	4	3·97	2	·58	S.	Good.
816	... ...	AC	...	...	...	...	20·7	2	...	...	·58	S.	
817			2330	7, 9	18 25 41	13 5 55	173·6	4	18·7	2	74·65	S.	
818			...	...	...	...	173·3	3	19·2	1	·72	S. Sm.	
819	55 B Tauri Poniat.		2342	6, 8½	18 29 41	4 50 29	10·0	4	28·4	2	·65	S.	
820	... ...		...	...	...	...	9·8	2	28·37	2	·65	S.	
821	... ...		...	...	...	...	9·3	2	28·1	2	·67	S.	
822			2346	7½, 9	18 31 26	7 25 50	289·1	4	18·7	1	·65	S.	
823			...	...	...	...	289·9	4	19·02	3	·65	S.	
824			2356	8½, 9	18 33 40	28 35 34	55·0	4	1·09	2	·65	S.	
825			...	...	...	...	54·8	4	1·18	2	·72	W. & S.	

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Dec. 1880.	Position-Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Observer.	Remarks.
				h m s	° ′ ″	°		″				
888		2437	7½, 7½	18 56 38	18 59 49	68·5	6	1·0	est.	73·55	W. S. H.	
889		...	...	...	...	67·0	3	0·86	3	·56	W. & S.	
890		...	...	...	...	68·3	4	0·8	est.	74·67	S.	
891	P. XVIII. 287	2438	7, 7½	18 55 30	58 3 34	...	...	...	...	73·58	S.	Not elongated; when 108 P. XIX. Draconis (0·8) was plainly divided.
892	P. XVIII. 302	2446	7½, 9	18 59 56	6 22 4	153·8	5	10·1	3	·55	W. S. H.	
893	... ...	...	...	...	...	153·5	4	9·9	2	74·67	S.	
894	L 35816=D 9		7, 11	19 0 51	43 42 36	176·0	4	2·13	2	73·55	W. & S.	Bears red illumination [well.
895	... ...		...	...	...	178·4	4	2·30	2	74·67	S.	
896		2454	8, 9	19 1 30	30 15 15	235·1	est.	1·0	est.	73·55	W. & S.	Elongated only; night [bad.
897		...	...	...	...	230·0	est.	...	...	·56	W. & S.	Ditto.
898		2455	7·2, 8.3	19 1 47	21 59 22	109·7	6	3·7	3	72·64	S.	
899		...	...	...	...	107·2	3	...	...	·55	A.M.W.	
900		...	...	...	...	109·2	4	3·42	2	73·55	W. & S.	
901		...	...	...	...	109·7	8	3·37	2	74·67	S.	
902	17 Lyræ	2461	6, 11	19 2 53	32 18 44	...	...	...	...	73·55	W. & S.	Failed to see B.
903	P. XIX. 8	2469	7½, 9½	19 3 42	38 44 16	120·9	4	1·333	1	·57	S.	Distance uncertain; cloudy.
904	P. XIX. 13 AB	2472	8½, 9½ 11, 12, [12, 12, 12	19 4 26	37 43 10	338·5	4	17·6	1	·55	W. & S.	A multiple star; several [faint companions.
905	... ... AC	...	...	...	...	348·9	3	...	...	·55	W. & S.	
906	... ... AE	...	...	...	...	331·1	1	...	...	·55	W.	
907	... ... AF	...	...	...	...	187·5	1	...	...	·55	W.	
908	... ... CD	...	...	...	...	292·7	4	5·57	3	·55	W. & S.	
909		2484	7½, 9	19 8 59	18 51 31	232·3	10	2·5	est.	74·73	W. S. Sm.	Extremely difficult.
910	6 B Cygni	2486	6, 6½	19 9 0	49 37 19	221·4	4	9·8	3	·72	W. & S.	
911	... ...	...	...	...	...	222·1	7	10·1	4	·78	W. S. Sm.	Three nights.
912	23 Aquilæ	2492	5½, 9½,	19 12 26	0 52 1	11·5	4	3·47	2	73·57	S.	B like 9th mag.
913	P. XIX. 108	2509	7, 8	19 15 42	62 59 22	341·6	5	0·81	2	72·64	S.	
914	... ...	...	...	...	...	341·4	4	0·81	1	73·58	S.	
915	... ...	...	...	...	...	342·3	7	0·66	1	74·73	S. Sm.	
916		2523	7·4, 7·5	19 21 37	20 55 18	150·1	4	6·5	2	73·57	S.	

917	22 B Cygni		2525	7, 7	19 21 40	27 4 40	232·6	4	...	...	72·64	S.	Scarcely divided.
918	... ...		...	...	...	...	225·8	2	0·5	est.	73·57	S.	Elongated.
919	... ...		...	...	...	...	237·8	2	0·5	est.	74·75	W. & S.	Dist. comp. at 82″ and 45″.
920	P. XIX. 149		2534	8, 8	19 23 22	36 17 2	63·3	16	...	...	71·82	{ W. S. C. P. R.	
921	... ...		...	...	...	...	62·5	4	7·2	6	·83	S.	
922	... ...		...	...	...	...	64·3	3	7·1	2	·86	A.M.W.	
923	... ...		...	...	...	...	64·1	4	6·9	2	73·57	S.	
924	... ...		...	...	...	...	64·3	3	7·1	3	74·75	W. & S.	Very unsteady.
925	β Cygni ...			3, 7	19 25 53	27 42 27	54·7	4	33·8	1	73·57	S.	
926		AB	2538	8, 8, 9	19 27 3	36 27 2	234·6	4	5·9	2	74·75	W. & S.	
927		AC	...	...	...	...	66·4	2	47·7	1	·75	W. S. L.	
928	169 P. XIX.	AB	2539	9, 11, 12	19 27 16	28 0 39	4·0	6	5·7	2	73·57	S.	More like 8½, 10.
929	... ...	...	...	...	...	...	0·8	5	5·5	2	74·75	W. & S.	
930	... ...	AC	...	...	...	...	241·8	1	45·0	est.	·75	W.	
931		AC	2544	7, 9½, 11	19 31 19	8 2 48	240·6	4	15·2	2	72·60	S.	AB not divided.
932		...	...	...	...	...	239·9	2	15·7	2	73·58	S.	
933		...	...	...	...	...	238·9	5	...	...	74·75	W. S. Sm.	
934		AB	...	...	...	...	213·0	2	0·5	est.	73·59	S.	
935		...	...	...	...	...	202·4	3	...	...	74·75	W. S. Sm.	Very doubtful; definition bad.
936		AB	2545	6½, 8½, 11	19 32 8	−10 25 37	317·9	4	4·1	2	73·57	S.	
937		AC	...	...	...	...	170·2	1	...	...	·57	S.	
938			2548	8, 9	19 31 28	24 44 0	101·2	7	9·8	2	74·75	W.S.Sm.L.	
939			2556	7, 7	19 34 17	21 58 50	...	...	...	...	73·57	S.	Not elongated.
940	P. XIX. 257		2570	7½, 9½	19 39 15	10 29 9	278·12	4	4·18	2	·59	S.	
941	... ...		...	...	...	...	281·75	4	3·57	2	74·75	W. & S.	
942			2576	7½, 7¾	19 41 0	33 19 53	304·2	5	3·32	3	72·63	S.	
943			...	...	...	...	306·4	7	2·93	2	·75	W. & S.	
944			...	...	...	...	304·2	4	3·23	2	73·59	S.	
945			...	...	...	...	307·6	6	3·51	4	74·73	W. S. Sm.	Bad definition; full moon.
946	17 Cygni		2580	5, 8	19 41 52	33 27 16	73·8	5	27·3	2	·75	W. S. Sm.	As bad as possible.
947	... ...		...	...	...	...	71·5	4	27·5	2	·75	W. S.	Better.
948	... ...		...	...	...	...	73·2	9	...	...	·79	W. S. Sm.	Bad readings.
949	π Aquilæ ...		2583	6, 7	19 43 3	11 31 1	118·2	4	1·7	4	71·58	S.	Almost equal.

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Dec. 1880.	Position-Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Observer.	Remarks.
				h m s	° ′ ″	°		″				
950	π Aquilæ	2583	6, 7	19 43 3	11 31 1	118·8	5	1·40	2	73·54	W.	Distance doubtful.
951	... ...	...	...	...	...	120·4	4	1·47	2	·59	S.	
952	... ...	...	...	...	...	121·3	6	1·57	3	74·75	W. & S.	Definition very bad.
953	D. 10 Vulpeculæ		8, 9	19 43 15	23 58 12	313·4	2	0·3	est.	72·61	S.	Very doubtful.
954	ζ Sagittæ...	2585	5, 9	19 43 39	18 50 26	311·2	6	8·8	5	73·56	W. & S.	Two nights.
955	α Aquilæ...		1½, 10	19 44 54	8 32 46	313·9	5	156·4	5	71·58	S.	
956	... ...		...	...	...	312·7	3	156·4	2	73·60	S.	
957	ε Draconis	2603	5½, 9	19 48 34	69 57 43	1·3	5	3·11	3	·73	W. & S.	
958	... ...	...	...	...	...	0·1	4	3·20	4	74·72	W. S. Sm.	
959	ψ Cygni ...	2605	5½, 8	19 52 32	52 7 14	183·7	4	3·3	8	71·58	S.	
960	... ...	...	...	...	...	182·8	4	3·65	4	·58	A.M.W.	
961	... ...	...	...	...	...	183·2	3	3·79	2	73·60		
962	A.C. 16 Vulpeculæ		7¼, 8	19 53 16	27 0 0	241·3	3	0·3	est.	·60	S.	Just elongated.
963	AB	2624	7, 8, 9½	19 59 1	35 41 14	175·8	5	1·91	2	74·75	W. S. Sm.	Definition bad.
964	AC	...	...	...	...	328·2	3	43·6	2	·75	W. S. Sm.	
965		2626	8, 8	19 59 27	30 12 9	73·4	1	0·8	est.	·76	W.	S. & Sm. agreed.
966	P. XIX. 415		8, 10	20 1 57	20 45 52	340·5	3	4·9	2	73·62	S.	
967	P. XX. 2		7, 10	20 3 40	16 33 34	13·0	3	6·6	2	·62	S.	Shaky.
968	... ...		...	...	...	14·2	7	6·1	2	·72	W. & S.	Night very good.
969		2640	7, 11	20 3 14	63 32 39	21·0	8	4·77	3	·73	W. & S.	B 10th mag. at least.
970	P. XX. 26	2644	7, 7·2	20 6 28	0 30 32	206·7	4	3·38	2	·62	S.	
971	153 B Cygni = A.C. 17		6, 11½	20 9 11	51 6 15	79·8	...	...	...	·62	S.	
972	... ...		...	...	...	82·7	2	12·0	est.	74·76	W. S.	A mere estimation.
973	Aquilæ 250 B	2656	7, 11½	20 9 46	7 26 29	...	...	...	...	·76	W. & Sm.	Failed.
974	172 B Cygni	2666	6½, 8½	20 13 52	40 21 27	246·4	6	2·82	4	·76	W. S. Sm.	
975	... ...	...	...	...	...	245·9	9	2·82	4	·79	W. S. Sm.	
976	κ Cephei ...	2675	4½, 8½	20 12 56	77 20 59	123·5	5	7·3	2	73·73	W. & S.	
977	176 B Cygni	2668	7, 9	20 15 54	39 1 30	289·9	5	3·13	2	74·76	W. S. Sm.	

978	176 B Cygni		2668	7, 9	20 15 54	39 1 30	292·2	9	3·04	2	74·79	W. S. Sm.	B looks like 10th mag.
979		AB	2673	8, 9½	20 17 6	12 57 27	329·4	6	1·92	2	·76	W. S. Sm.	Distance very uncertain; [stars nebulous.
980		AC	&	...	...	...	104·8	2	75·0	est.	·76	W. & S.	
981		CD	2674	8, 11	...	...	358·8	2	14·8	1	·76	W. & S.	
982	Draconis 275 B		2684	6	20 19 34	68 29 45	...	...	...	...	·85	W. & S.	B not seen.
983	P. XX. 178	AB	2690	7½, 8, 9, 16	20 25 29	10 51 24	255·3	5	15·2	3	71·53	W. & S.	D not seen.
984	... ...	...	...	...	...	...	256·3	4	15·39	2	73·68	S.	
985	... ...	BC	...	...	...	...	220·0	est.	...	...	71·53	W. & S.	Very difficult.
986	... ...	...	...	...	...	...	227·3	1	...	...	73·68	S.	
987	44 Cygni = A.C. 18			6½, 11⅓	20 26 27	36 31 42	158·6	4	...	...	·68	S.	Too faint for distance [measures.
988			2696	8, 8½	20 27 35	5 2 2	303·4	5	0·66	1	72·64	S.	Clearly divided; night good.
989			...	...	...	...	305·2	4	0·85	1	73·69	S.	Not well divided.
990			2708	7, 8·3	20 34 8	38 13 20	335·5	4	21·0	2	·69	S.	
991			...	...	...	...	335·0	5	21·0	2	·72	W. & S.	Satisfactory; stars steady.
992			...	...	...	...	334·7	3	21·2	2	74·76	W. S. & Sm.	
993	49 Cygni ...		2716	6, 8	20 36 11	31 52 50	50·8	4	2·97	2	73·69	S.	
994	... ...		...	...	...	...	50·1	6	3·3	4	74·79	W. & S.	Night extremely bad.
995	114 B Arietis			7·3, 8·2	20 40 9	18 48 0	231·2	4	2·7	2	72·99	S.	
996	52 Cygni ...		2726	5¼, 9½	20 40 43	30 16 52	60·9	4	6·6	2	73·69	S.	
997	γ Delphini		2727	4, 5	20 41 6	15 41 40	271·7	4	11·1	2	·69	S.	
998	λ Cygni ...		[413]	5·7, 6·7	20 42 44	36 3 24	88·5	4	0·45	1	72·65	S.	
999	... ...		...	...	...	...	93·7	2	...	...	73·69	S.	Scarcely elongated.
1000	P. XX. 376		2735	6, 8	20 49 40	4 4 27	287·5	5	1·87	2	·72	W. & S.	Night hazy, but steady.
1001	ε Equulei	AB	2737	5½, 7½, 7½	20 53 5	3 50 7	287·2	5	0·86	2	72·65	S.	B apparently 6th.
1002	... ...	...	...	...	...	...	285·2	8	1·09	2	·85	W.	B brighter than C.
1003	... ...	...	...	...	...	...	286·9	6	1·15	3	73·70	W. S.	Night not good.
1004	... ...	AC	...	...	...	...	76·2	4	9·3	2	72·65	S.	
1005	... ...	...	...	...	...	...	75·9	4	...	...	·85	W.	
1006	... ...	...	...	...	...	...	73·7	5	10·10	3	73·70	W. & S.	Night not good.
1007	P. XX. 429		2741	6, 7½	20 54 39	49 59 43	31·4	9	2·05	6	74·85	W. & S.	Two nights.
1008	2 Equulei		2742	6, 6½	20 56 18	6 42 30	225·2	4	2·93	4	73·72	W. S. H.	Night very bad.
1009			2744	6·3, 7·1	20 56 58	1 3 39	175·2	4	1·27	2	72·65	S.	
1010			...	...	...	...	175·7	6	1·60	3	73·72	W. S. H.	

	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Dec. 1880.	Position-Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Observer.	Remarks.
				h m s	° ′ ″	°		″				
1011	12 Aquarii	2745	5½, 8½	20 57 44	− 6 17 52	191·0	5	3·10	3	73·72	W. S. H.	
1012	61 Cygni ...	2758	5½, 6	21 1 16	38 6 52	113·1	5	19·1	5	71·59	S.	
1013	... ...	...	...	...	...	115·6	6	19·0	2	72·65	S.	
1014	... ...	...	...	...	...	114·2	4	...	...	·72	W.	
1015	... ...	...	...	...	...	114·4	4	...	...	·73	W.	
1016	... ...	...	...	...	...	114·0	7	...	...	·74	A. M. W.	
1017	... ...	...	...	...	...	114·5	5	...	...	·74	W.	
1018	... ...	...	...	...	...	114·7	4	18·7	2	·75	W.	
1019	... ...	...	...	...	...	114·7	9	...	3	73·72	H.	
1020		2760	7, 8	21 1 53	33 39 7	224·4	5	9·5	3	·72	W. & H.	
1021	P. XXI. 1	2762	6½, 9	21 3 33	29 43 15	313·6	4	3·43	3	·72	W. & H.	
1022		2767	8, 8¼	21 5 1	19 28 16	31·5	6	2·54	2	·73	W. S. H. M.	
1023		[431]	8, 8¼	21 6 59	40 46 3	120·4	6	3·09	2	·73	W. S. M.	
1024	AB	2776	7, 9, 10	21 8 55	−10 50 49	52·1	4	...	...	·73	W. & S.	
1025	AC	...	...	...	...	338·9	9	5·33	2	·73	W. & S.	Difficult.
1026	P. XXI. 51	2780	6½, 7½	21 8 45	59 29 35	224·3	5	1·07	2	·81	W. S. H.	
1027	... ...	...	...	...	...	225·0	5	1·04	3	74·85	W. S.	
1028	P. XXI. 50	[432]	7, 7¼	21 9 44	40 39 39	128·4	5	1·17	2	73·73	W. & S.	
1029		2784	8, 10·5	21 11 11	73 33 46	347·5	8	14·6	2	74·85	W.	
1030	11 Arg. xxi. Cephei		7¼, 7½	21 11 29	63 57 21	247·4	4	0·93	2	72·78	S.	
1031	= A.C. 19		...	...	...	251·2	4	0·99	1	73·81	W. S. Sm.	
1032		[437]	7, 7	21 15 57	31 57 39	51·4	5	1·32	2	·73	W. S. Sm.	
1033	20 B Pegasi	2799	6, 5, 7·4	21 23 2	10 33 37	314·0	8	1·36	2	72·66	S. & D.	
1034	... ...	...	...	...	...	312·5	5	1·28	2	73·73	W. S.	Satisfactory.
1035	29 B Pegasi	2804	7, 8	21 27 26	20 10 57	325·0	4	...	...	71·99	S.	Unsatisfactory; foggy.
1036	... ...	...	...	...	...	327·3	4	2·91	2	72·66	S.	
1037	... ...	...	...	...	...	327·5	5	2·8	2	73·73	S. Sm.	
1038	β Cephei ...	2806	3, 8	21 27 6	70 2 2	250·9	5	13·4	3	·79	W. & S.	
1039		[443]	7¾, 8	21 31 37	6 9 54	350·2	4	8·3	3	·73	W. & S.	

1041	P. XXI. 240	AD	2810	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
1042	... ...	...	...	...	...	...	122·0	4	11·7	2	74·85	W. S.	
1043	... ...	AC	...	...	...	...	339·9	4	19·8	2	73·81	W. S. H.	
1044	... ...	...	...	...	...	...	340·2	2	19·7	2	74·85	W. S.	
1045	... ...	AD	...	...	...	...	174·2	2	50·0	est.	·85	W. & S.	
1046	P. XXI. 256		2819	8, 9	21 36 38	57 2 13	57·3	4	12·6	2	73·81	W. & S.	
1047	μ Cygni ...		2822	4·3, 7	21 38 45	28 12 14	...	...	4·12	4	71·68	W.	
1048	... ...		...	...	...	...	118·5	5	3·91	2	73·73	W. & S.	
1049	... ...		...	...	...	...	117·6	3	3·83	3	·73	W. & S.	
1050	... ...		...	...	...	...	117·6	3	...	...	·78	W. & H.	Night good.
1051	κ Pegasi ...		2824	4, 13	21 39 12	25 5 37	301·7	4	11·6	4	71·51	S.	
1052	... ...		...	...	...	...	301·8	5	11·8	2	73·73	W. H. Sm.	
1053	Cephei 147 B		2840	6, 7	21 47 57	55 13 58	195·4	4	19·9	2	74·85	W. & S.	
1054			2846	8·5, 10·3	21 50 7	45 13 26	155·0	3	25·0	est.	·85	W. & S.	Triple; D 10th mag.
1055	ξ Cephei ...		2863	5, 7	22 0 17	64 2 29	284·7	8	6·5	7	71·92	W. & S.	
1056	... ...		...	...	...	...	284·1	4	6·4	4	·81	W. & S.	
1057		AC	[464]	8, 8, 10	22 6 1	39 34 40	352·9	6	32·4	2	74·85	W. S. Sm.	B not seen.
1058	P. XXII. 33		2877	6·5, 9·5	22 8 33	16 35 54	349·0	4	9·8	2	72·66	S.	
1059	... ...		...	...	...	...	348·2	7	9·8	1	73·73	W. Sm. H.	
1060	... ...		...	...	...	...	349·1	6	9·7	2	74·84	W. Sm.	Definition excellent.
1061	148 B Pegasi		2878	7½, 9	22 8 30	7 22 52	128·9	14	1·26	4	73·80	W. S. H.	Very shaky.
1062			2881	6·7, 7·3	22 9 6	28 57 41	107·0	8	1·8	2	74·84	W. & Sm.	Definition very good, but position doubtful.
1063			...	...	...	...	104·5	8	1·84	2	·85	W. S. Sm.	Difficult; measures vary.
1064	P. XXII. 65		2894	6·5, 9	22 13 40	37 9 56	193·2	4	15·4	2	73·73	W. & Sm.	
1065	... ...		...	...	...	...	194·9	5	15·5	2	74·85	W. S. Sm.	
1066	... ...		...	...	...	...	194·9	5	15·4	2	·85	W. S. Sm.	
1067			2895	8, 9½	22 15 8	24 21 11	28·9	6	6·4	2	·85	W. S. Sm.	Night fair.
1068			...	...	...	...	28·0	6	6·6	2	·85	W. S. Sm.	
1069	33 Pegasi	AB	2900	6, 10, 8	22 17 52	20 14 31	175·8	4	...	...	71·93	W.	B very faint.
1070	... ...	...	...	...	...	...	176·5	2	...	...	73·73	W. Sm.	Very shaky.
1071	... ...	...	...	...	...	...	177·0	4	...	...	74·84	W.	
1072	... ...	...	...	...	...	...	175·5	4	1·8	2	·85	W. & S.	

Ref. No.	Name of Star.		Struve's No.	Mags.	R.A. 1880.	Dec. 1880.	Position-Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Observer.	Remarks.
					h m s	° ′ ″	°		″				
1073	33 Pegasi	AC	2900	6, 10, 8	22 17 52	20 14 31	331·7	4	62·7	5	71·61	S.	B not seen.
1074	... ...	...	...	...	...	...	330·0	4	62·4	2	·93	W.	
1075	... ...	...	...	...	...	...	331·2	2	...	...	73·73	W. Sm.	
1076	... ...	...	...	...	...	...	331·4	3	62·0	2	74·85	W. S. Sm.	
1077	ζ Aquarii ...		2909	4, 4·2	22 22 38	− 0 38 7	...	...	3·79	8	71·61	S.	
1078	... ...		...	...	...	...	335·2	4	3·81	4	·75	W.	
1079	... ...		...	...	...	...	336·2	4	3·7	2	72·67	S.	Great tremor.
1080	... ...		...	...	...	...	335·7	4	3·9	3	·71	W.	Ditto. [possible.
1081	... ...		...	...	...	...	336·6	5	...	...	·74	W. & A.M.W.	Measures almost im-
1082	... ...		...	...	...	...	334·3	6	3·52	2	73·73	W. Sm.	
1083	... ...		...	...	...	...	335·3	3	...	...	·78	W. & L.	
1084	... ...		...	...	...	...	335·1	4	3·48	3	·81	W. S.	
1085	... ...		...	...	...	...	335·7	2	3·78	4	·83	W.	Extremely bad night.
1086			2910	8, 9	22 22 31	22 55 18	343·6	7	5·26	3	74·85	W. S. Sm.	
1087			...	...	...	...	343·7	5	5·34	2	·85	W. S. Sm.	[72·75.
1088	37 Pegasi		2912	6, 7	22 23 54	3 49 26	...	...	...	...	72·71	W.	Elongated only; also on
1089	... ...		...	...	...	...	119·3	4	0·5	est.	73·78	W. & H.	Night middling.
1090	... ...		...	...	...	...	...	...	...	...	74·84	W.	Failed.
1091			2917	8, 8	22 25 50	52 54 47	73·3	6	4·93	2	73·81	W. H. Sm.	
1092			...	...	...	...	72·0	6	4·66	2	74·84	W. Sm.	Definition excellent.
1093			2924	5, 6	22 29 33	69 17 29	265·3	3	1·24	2	73·83	W. S. H.	
1094			...	...	...	...	266·5	6	1·23	2	74·84	W. Sm.	Definition very good.
1095			2925	8, 9	22 31 50	5 17 1	2·8	3	7·5	1	73·83	W.	Very unsteady.
1096			...	...	...	...	3·8	3	...	...	·78	W. & H.	Fair definition.
1097			2928	8, 8·3	22 33 10	−13 13 58	318·8	3	4·42	2	72·71	W.	Very faint.
1098			...	...	...	...	316·0	5	3·86	1	·75	W.	
1099			2934	7·7, 9	22 36 3	20 48 25	164·1	1	...	...	·71	W.	Night very bad.
1100			...	...	...	...	163·8	6	1·22	2	73·78	W. H.	Hazy.
1101			...	...	...	...	162·0	5	1·15	2	74·84	W. Sm.	Definition very good.

1102			[478]	6½, 9	22 38 39	38 50 21	281.1	2	...	...	73.78	W.	B very red.
1103	P. XXII. 219	AC	2944	7, 7, 8	22 41 40	− 4 50 50	142.5	4	48.2	1	72.78	S.	
1104	... ...	...	...	...	...	...	141.7	1	...	...	.77	S.	
1105	... ...	...	...	...	...	...	141.5	3	...	...	73.78	W.	
1106	... ...	AB	...	...	...	...	254.1	3	3.4	2	.78	W.	
1107	... ...	BC	...	...	...	...	137.2	1	...	...	.77	S.	
1108	263 B Pegasi		2958	6, 9	22 50 51	11 12 28	9.7	13	3.94	5	74.85	W. S. Sm.	B 10th. Two nights.
1109	52 Pegasi...		[483]	6½, 8	22 53 12	11 5 39	202.2	4	1.40	2	73.83	W.	Very unsteady.
1110	... ...		...	...	...	...	204.2	15	1.21	6	.82	W. & S.	Three nights.
1111	... ...		...	...	...	...	203.9	4	1.43	2	74.84	W.	Good definition.
1112			2968	7½, 11	22 54 59	30 26 39	91.6	5	3.08	2	73.78	S.	
1113			2976	8.5, 9.8, 9.9	23 1 37	5 57 20	187.2	4	16.5	2	.78	S.	
1114			...	...	...	...	186.7	2	16.6	1	.79	W.	
1115	P. XXII. 306		2978	7, 8½	23 1 43	32 10 36	145.7	4	8.6	2	.78	W.	
1116	π Cephei A a			5, 10	23 4 4	74 44 20	...	...	1.23	2	72.80	W. & S.	Position doubtful.
1117	... ...			...	...	...	21.4	2	1.38	2	73.81	S.	Difficult, & very doubtful.
1118	... ...			...	...	...	19.3	4	1.26	2	74.84	W. & Sm.	Definition very good.
1119			2995	8, 8	23 10 23	− 2 14 30	28.8	3	5.12	3	73.85	W.	
1120	ο Cephei ...		3001	6, 8.5	23 13 41	67 27 16	188.0	4	2.57	2	72.80	W. & S.	Definition good.
1121	... ...		...	...	...	...	181.0	4	2.69	2	73.82	W. & H.	Def. very good, but read- [ings very different.
1122	... ...		...	...	...	...	191.0	4	2.56	2	74.84	W. & Sm.	
1123	... ...		...	...	...	...	189.6	4	2.81	3	.85	W. S.	Definition bad.
1124			[494]	8, 8½	23 14 45	21 17 48	82.8	5	3.25	2	73.79	W. S. H.	
1125			3006	8½, 9	23 15 25	34 47 10	170.4	5	4.92	4	.80	W. & S.	
1126			...	...	...	...	173.2	6	4.92	2	74.85	W. S. Sm.	Bad definition.
1127			...	...	...	...	172.7	4	4.97	2	.85	W. S. Sm.	
1128	P. XXIII. 69		3008	6.2, 7.5	23 17 32	− 9 7 5	248.1	3	4.8	1	72.75	M.	
1129	... ...		...	...	...	...	249.0	4	5.02	1	.75	W.	
1130	... ...		...	...	...	...	248.5	4	5.17	3	.85	W.	
1131	287 B Cephei	[Bb	3017	7½, 9	23 22 54	73 27 27	34.1	4	2.00	4	73.81	W. S. H.	
1132	101 P. XXIII.	Cass.		5, 7½, ?, 14	23 24 29	57 53 0	222.3	7	1.7	est.	.81	W. S. Sm.	4 stars, A, B, b, C.
1133			[500]	7, 8	23 30 46	43 45 8	140.8	6	0.66	1	74.86	S. Sm.	Elongated only.
1134			[503]	8, 8½	23 35 58	19 38 51	128.8	8	1.79	2	73.81	W.S.H.Sm.	

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Dec. 1880.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Observer.	Remarks.
				h m s	° ′ ″	°		″				
1135		[503]	8, 8½	23 35 58	19 38 51	131·1	4	1·63	3	74·86	S. Sm.	
1136	6 Cassiopeiæ	[508]	6, 8½	23 42 58	61 32 57	197·2	3	1·73	3	73·83	W. S. H.	
1137	... ...	...	...	...	...	196·5	5	1·73	2	74·84	W. Sm.	Definition very good.
1138		[510]	8, 8	23 45 7	41 20 57	...	...	...	...	·86	S. Sm.	Not divided, or not found.
1139		3046	8, 8·3	23 50 14	−10 9 51	240·5	5	...	...	72·89	W.	Very hazy; one reading [242·6.
1140		3047	8, 8, 5	23 51 49	56 43 15	72·0	5	1·02	2	73·82	W. & S.	Nearly equal.
1141		...	...	...	...	72·0	4	1·07	2	74·86	S. Sm.	
1142	σ Cassiopeiæ	3049	6, 8	23 52 55	55 5 14	326·2	5	3·42	3	73·83	W.S.H.Sm.	Night not very good.
1143	37 B Andromedæ	3050	5·7, 6·3	23 53 22	33 3 37	202·2	5	2·94	4	71·94	S.	Very unsteady.
1144	... ...	...	...	...	...	201·0	6	2·93	3	72·89	W. & M.	Satisfactory.
1145	... ...	...	...	...	...	200·7	5	3·21	2	·80	M.	Night not very good.
1146	... ...	...	...	...	...	201·0	4	3·13	2	·80	W.	
1147	... ...	...	...	...	...	202·1	9	3·01	4	·80	W. S. M.	
1148	... ...	...	...	...	...	202·1	8	3·20	4	73·81	W.S.Sm.H.	
1149		3061	8, 8¼	23 59 35	17 10 23	147·1	2	7·5	1	·81	W. S.	
1150	B.A.C. 8372	3062	6½, 7·3	23 59 57	57 46 1	286·3	4	1·45	2	72·80	W.	
1151	... ...	...	...	...	...	287·8	8	1·45	3	73·82	W. H. Sm.	Very good definition.
1152	... ...	...	...	...	...	291·2	8	1·37	2	74·86	S. Sm.	

IV.—*Measures of* 484 *Double Stars, made at* MR. EDWARD CROSSLEY'S *Observatory, Bermerside, Halifax.*

By MR. JOSEPH GLEDHILL, F.R.A.S., F.G.S., &c.

THE measures of Double Stars given below form part of the results of a scheme which had for its object a complete review of all known and suspected binaries, and a diligent search for new binaries among the large number of double stars measured by the HERSCHELS, STRUVE, and others, in the early years of this century.

The work was taken up here, systematically, about the middle of 1873, in concert with Mr. WILSON, of the Rugby Observatory. It was part of our plan to throw the complete results into the form of an Observatory Handbook, giving the names, synonyms, R. A. and Dec. (1880), magnitudes, and colours of the stars; also a short history of each binary, with complete lists of measures. A chapter on Sir JOHN HERSCHEL'S graphic method of finding the orbits of binaries, with an example fully worked out, and one on micrometers, were also to be given.

Already several hundreds of doubles have been examined, and scores struck off our lists as needing no further measurement for the present. Measures of many of these apparently fixed doubles will be found in the subjoined list. Many of the double stars discovered by OTTO STRUVE, DAWES, and ALVAN CLARK have also been measured several times; but owing to the extreme difficulty of many of those in OTTO STRUVE'S list, and the paucity of observations of those named after the other two observers, it was thought best to withhold the results until more good measures had been obtained.

On looking over our work at the end of 1874, and seeing, with some disappointment, how little had been done, owing to the bad observing weather, it was resolved to send to the Society at once such measures as were deemed likely to interest the members. And for convenience of reference it was

arranged that the Rugby and Bermerside lists should be presented simultaneously, so that they might appear in the same volume of the Society's *Memoirs*.

It was found quite impossible to observe the colours of the stars, owing to the very great delay such a plan would have entailed. The extreme rarity of really fine nights, the necessary use of coloured light for the micrometer, and the want of special training of the eye, all forbade us to attempt the scrutiny of colour.

The magnitudes have been taken mostly from STRUVE.

The positions have been reduced from STRUVE's "*Stellarum Fixarum imprimis duplicium et multiplicium Positiones mediæ pro epocha* 1830." Some, not given in this work, were taken from SMYTH; some from DAWES, and a few from other sources. Where possible, the R. A. and Dec. have been given to the nearest second.

The instrument used is an excellent 9⅓-inch equatoreal refractor by COOKE, with driving-clock and parallel-wire micrometer. The usual working power was about 400; on fine nights 750 was frequently used on close objects.

In conclusion, it is difficult to avoid recurring to the dreadful observing weather already alluded to. Here, at any rate, it was most distressing. The 365 days of 1874 brought but 8 fine observing nights or parts of nights: 45 were just fair and 42 were decidedly bad; and August 1873 did not afford a single night fit for observation. The average number per month of nights clear throughout was 4. And the present year, as yet, is not more cheering; for January brought but one night clear throughout, and February only two.

Ref. No.	Name of Star.	No.	Mags.	[illegible]	[illegible]	Angle.	Obs.				
				h m s	° ′ ″	°		″			
1	... ...	1	8, 10	0 2 39	36 32 53	286·4	4	10·0	4	73·91	Definition not good.
2	51 B Androm. H ii. 83	3	7·5, 8·5	3 49	45 43 24	84·0	4	4·3	3	·96	Fair.
3	... ...	10	7·5, 8·2	8 23	62 10 24	176·2	2	18·0	est.	·91	Bad night.
4	35 Piscium. H iii. 62 ...	12	6·2, 7·8	8 47	8 9 18	148·0	5	11·48	5	·91	
5	318 B Cephei ...	13	6, 6·5	9 25	76 17 3	101·0	6	0·5	est.	·91	Fair results.
6	38 Piscium. H ii. 50 ...	22	8, 8	11 13	8 12 23	238·36	5	4·67	4	·89	Bad night.
7	... ...	23	8, 10	11 20	− 0 21 4	353·41	4	6·6	4	·91	Distance bad.
8	69 B Andromedæ ...	24	7·2, 8	12 16	25 28 29	247·9	4	5·2	5	·91	
9	42 Piscium	27	6·8, 10·7	16 13	12 48 56	338·0	3	29·0	est.	·89	No definition.
10	49 Piscium	32	7, 10	24 23	15 22 29	106·78	4	16·4	5	·94	Fair.
11	51 Piscium. H iv. 70 ...	36	5, 9	26 12	6 17 33	82·6	5	29·9	est.	·91	Sky bad.
12	... ...	41	8, 11, 11	28 38	38 30 24	189·3	4	16·4	4	·91	Small star difficult.
13	... ...	44	8, 9	31 56	40 19 35	264·6	4	8·9	4	·91	
14	63 B Cassiopeiæ ...	45	7, 10	32 7	46 17 49	85·5	5	11·0	est.	·89	
15	55 Piscium	46	5, 8	33 36	20 46 50	191·8	5	6·6	5	·91	
16	... ...	54	9, 10	37 55	32 52 48	195·4	5	18·5	5	·93	
17	... ...	55	8, 8·8	37 55	32 57 40	326·4	5	1·7	5	·93	
18	P. O. 181	59	7, 8	41 11	50 47 24	148·5	4	...	...	·89	
19	24 Cassiopeiæ η ...	60	4, 6	41 43	57 11 9	135·7	5	6·15	5	70·65	
						135·8	5	6·13	5	·70	
						136·0	5	6·0	5	·80	
						137·6	5	6·07	5	71·6	
						138·3	5	6·0	5	·8	
						143·1	5	6·1	5	73·51	
						143·8	6	5·8	8	·74	
						144·3	7	...	...	·81	
20	65 Piscium	61	6, 6	43 26	27 3 23	298·1	4	4·7	4	·91	
						297·7	4	4·5	4	·93	

Ref. No.	Name of Star.		Struve's No.	Mags.	R.A. 1880.	Decl. 1880.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Remarks.
					h m s	° ′ ″	°		″			
67	259 B Andromedæ ...		228	6·8, 7·2	2 6 21	46 55 29	307·2	2	0·6	est.	74·94	
68	66 Ceti. H iv. 25 ...		231	6, 7·8	6 39	− 2 57 13	229·2	4	16·4	4	73·91	Bad definition.
							228·9	3	16·5	4	·93	
69	... ...		234	7·8, 8·7	8 33	60 47 54	226·1	3	0·45	est.	·94	Extremely difficult.
70	... ...		241	8·5, 10	12 10	73 33 18	286·0	1	20·0	1	74·01	Extremely difficult.
71	... ...		249	7, 9	13 58	44 3 1	190·4	4	2·8	4	73·98	Violent motion.
72	... ...		254	9, 9·5	14 48	23 4 47	343·5	3	12·7	3	·93	Bad definition.
73	ι Cassiopeiæ	AB	262	4·7, 7·5	19 10	66 51 46	265·3	3	1·8	4	·94	
							266·7	2	2·0	2	·98	
							265·7	6	1·9	5	74·93	
		AC	...	...	...	...	109·0	5	7·9	5	73·94	
							107·5	2	7·9	3	·98	
74	... ...		263	9, 10	19 34	60 7 0	101·5	1	15·0	est.	74·01	
75	... ...		264	8, 11·2	20 40	60 7 14	224·5	1	16·5	est.	·01	
76	P. II. 89		269	8·5, 11	21 9	29 20 8	347·1	5	1·2	4	73·94	
							346·5	3	...	...	74·02	Bad night.
77	... ...		273	7·7, 8·7	25 23	17 50 35	1·5	1	6·8	1	·01	
78	... ...		276	9, 9	26 20	5 48 17	256·0	3	2·3	1	73·93	
79	... ...		280	7, 8	28 8	− 6 9 48	347·0	1	3·6	1	·93	Cloudy.
80	33 Arietis. H iv. 5 ...		289	6, 8	33 40	26 32 47	1·0	4	29·4	4	·94	
81	84 Ceti		295	6, 10	35 4	− 1 12 11	325·0	5	4·7	4	·94	
82	... ...		293	8·5, 11·7	35 31	56 32 56	71·0	2	7·7	2	·96	
83	θ Persei. H iii. 58 ...		296	4·2, 10	35 58	48 43 20	295·5	2	16·3	1	·93	
84	γ Ceti		299	3, 6·8	37 5	2 43 58	292·7	4	2·5	3	·98	
85	114 B Arietis ...		305	7, 8	40 41	18 51 32	320·6	3	2·6	3	·94	
86	π Arietis. H i. 64	AB	311	4·9, 8·4, 10·2	42 36	16 57 56	121·2	5	3·2	3	74·01	Much motion.
							122.5	3	3·0	1	·02	
87	85 B Persei. H i. 38 ...		314	6·9, 7·1	44 21	52 30 16	301·3	3	...	...	·02	
88	... ...		323	8, 8	46 19	5 59 0	279·8	3	2·6	3	·03	

91	... ...	...	329	7·5, 9	51 56	58 33 30	274·1	1	10·2	1	·03	
92	ε Arietis ...	...	333	5, 6	52 21	20 51 40	198·0	...	1·0	...	70·65	
							199·7	2	1·07	4	73·94	
93	... ...	...	345	8, 9·8	1 7	78 3 0	83·0	3	6·9	3	74·03	
94	... ...	...	344	8·9, 9·7	3 5 0	84 12 57	149·7	2	2·6	3	·03	Very difficult.
95	... ...	...	380	9, 10	15 17	8 19 47	73·2	4	1·3	4	73·94	
96	... ...	...	389	7, 8	20 31	58 57 9	63·3	4	2·7	4	·94	
97	... ...	...	408	8, 8·2	24 40	− 4 41 3	339·2	4	1·4	4	·93	
98	... ...	...	400	7, 8	25 13	59 38 9	295·0	1	1·2	3	·96	
99	7 Tauri ...	...	412	6·6, 6·7	27 20	24 3 44	232·0	3	0·4	est.	·94	Very difficult.
100	P. III. 98 Eridani	...	422	6·2, 8	30 38	0 11 54	240·0	3	6·4	4	·94	
101	Ḫ ii. 52 ...	...	425	7·3, 7·3	32 32	33 43 33	102·1	5	3·0	5	·91	
102	49 Hev. Cephei	...	460	5·5, 6·5	49 57	80 22 7	27·3	3	0·6	est.	·94	
							29·3	3	0·8	est.	74·12	
103	... ...	...	462	9, 10·7	46 42	52 0 56	133·0	5	8·6	4	73·94	Very difficult.
104	32 Eridani. Ḫ II. 36	...	470	5·5, 7	48 16	− 3 18 34	347·5	5	6·5	4	·94	
105	P. III. 219 ...	AB	479	7, 7·9, 9·4	53 49	22 51 50	125·6	6	7·7	5	·91	
							127·2	5	7·6	5	·94	
		AC	...	...	...	...	240·0	2	58·5	2	·91	
							240·7	1	59·0	1	·94	
106	... ...	...	497	8·5, 10·7	4 2 3	8 7 35	234·0	2	13·4	2	·96	Bad sky.
							234·7	2	13·3	1	74·04	Clock won't drive.
107	... ...	...	504	8·5, 10	6 30	67 16 43	264·6	4	6·9	4	·04	
108	... ...	...	506	9, 9·2	7 49	70 7 43	292·9	3	9·4	3	·04	
109	... ...	...	516	6, 9	8 41	−10 33 6	151·4	4	6·3	4	·04	
110	... ...	...	517	7·5, 9·2	9 51	0 9 20	8·5	3	4·2	4	·04	
111	... ...	...	536	8, 9	16 13	− 4 57 35	160·0	5	1·3	5	·04	
112	230 B Tauri	...	535	7, 8	16 39	11 5 56	339·7	5	1·8	5	73·94	
113	... ...	...	542	7, 9	19 0	45 59 10	105·0	2	21·9	1	74·04	
114	Ḫ ii. 54 ...	...	546	8, 9	20 0	18 51 9	186·0	2	7·3	2	73·98	Bad sky.
115	Ḫ iii. 100 ...	...	570	5·5, 6·5	29 30	− 9 59 0	260·0	1	13·0	1	74·00	„ „
116	4 B Aurigæ...	...	572	6·2, 6·5	31 4	26 42 6	214·2	4	3·4	4	·04	

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Decl. 1880.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Remarks.
				h m s	° ′ ″	°		″			
117	... ...	577	7.5, 8	4 34 9	37 17 0	260.9	4	1.35	4	73.94	
118	... ...	589	8, 8	38 27	5 4 9	303.5	2	4.4	3	.98	Bad definition.
119	... ...	596	8, 10	40 15	−12 10 4	283.5	3	10.4	3	.96	
120	7 Camelopardali ...	610	4.2, 11.3	47 40	53 33 36	240.0	2	25.9	2	.96	Not good.
121	... ... AB	613	7.7, 8.7, 11.7	50 12	43 57 17	105.0	2	18.2	4	.96	
	AC	...	...	...	...	18.6	4	15.7	3	.96	
122	... ...	620	8, 9	51 32	13 46 14	230.0	2	3.8	2	74.04	
123	... ...	644	6, 6	5 2 11	37 8 56	42.0	1	1.7	1	.04	Clock refuses to drive.
124	... ...	646	8, 9	2 46	39 7 47	73.0	1	16.0	1	.04	
125	ρ Orionis	654	5, 8	7 1	2 43 8	64.5	2	7.5	1	.06	Bad night.
126	14 Aurigæ. H iv. 19 AB	653	5, 7.2, 11	7 36	32 32 54	225.2	3	14.8	3	73.96	
						224.7	2	14.7	2	.98	
	AC	...	...	...	...	340.9	3	11.7	2	.96	
						344.0	1	11.9	1	.98	Bad night.
127	β Orionis. H ii. 33 ...	668	1, 7	8 46	− 8 20 24	201.1	3	9.7	3	.94	
						198.3	4	9.4	3	.99	Very unsteady discs.
						200.6	5	9.5	2	74.00	" "
128	... ...	675	8.8, 9	10 12	− 5 45 47	1.5	1	9.8	1	.06	Stars swing about.
129	... ...	684	8, 9.5	13 24	44 57 42	141.0	2	1.57	2	.06	
130	... ...	686	7.9, 8.1	13 37	23 55 3	221.0	1	9.1	1	.06	No stillness.
131	23 Orionis. H iv. 84 ...	696	5, 7	16 31	3 25 44	27.5	5	32.1	4	.06	Violent motion.
132	... ...	694	8.2, 8.2	16 39	24 50 54	358.0	4	1.4	4	73.98	" "
133	η Orionis. D. 5 ...	...	4, 5	18 26	− 2 30 30	85.1	4	1.34	5	73.94	
						86.5	5	1.0	est.	.99	Very difficult, except when the sky is good.
						87.3	3	...	...	74.09	
						88.5	3	1.0	est.	.10	
						84.0	7	...	...	.11	
						88.0	3	1.25	5	.13	
						86.3	3	...	...	.16	
						86.3	5	1.2	5	.17	

137	32 Orionis. H i. 25 ...	728	5·2, 6·7	24 22	5 51 25	190·0	3	0·6	est.	·14	Very difficult.
138	... ...	727	8, 9·5	25 5	44 41 58	64·5	4	2·4	4	·16	
139	... ...	733	8·7, 9·5	26 15	15 51 53	40·0	1	12·3	3	·14	Cloudy.
140	380 B Tauri. H i. 70 ...	742	7·5, 7·7	29 14	21 55 11	255·1	4	3·4	3	73·94	Restless image.
						256·6	4	3·2	4	·98	" "
141	26 Aurigæ. H iii. 64 ...	753	5·8, 8	30 56	30 25 16	268·0	4	12·2	4	·98	
142	ζ Orionis. H iv. 21 ...	774	2, 5·7	34 42	− 2 0 20	152·5	4	2·5	4	·93	
143	... ...	785	7, 8	38 29	25 51 52	350·0	4	14·7	4	74·16	Frightful motion.
144	... ...	787	8, 8	38 50	21 16 14	60·6	4	1·3	4	·16	
145	... ...	796	7, 8	42 7	31 44 52	62·5	4	3·6	4	·14	Pretty good.
146	... ...	807	7·3, 9·3	44 43	34 24 26	145·5	4	1·8	4	·16	
147	... ...	811	8, 9·5	46 33	30 28 4	237·0	4	5·1	4	·16	
148	... ...	817	8·2, 8·3	48 23	7 0 32	70·2	4	18·8	4	·16	
149	... ...	821	8, 10	50 44	29 36 47	10·5	4	2·3	4	·16	
150	.. ..	844	8·2, 8·8	6 1 30	14 0 48	8·7	4	23·2	4	·10	Clock won't drive.
151	... ...	850	8·5, 10·2	1 35	− 3 57 44	15·0	4	1·8	4	·10	
152	... ...	854	8·4, 10	2 22	5 48 2	320·4	4	5·5	4	·10	
153	41 Aurigæ. H iii. 82 ...	845	5·2, 6·4	2 25	48 44 12	353·0	4	8·0	4	·10	
154	... ...	856	8·3, 10·5	2 34	7 5 2	49·0	4	9·2	4	·13	
155	... ...	860	8, 10	3 42	24 54 22	357·88	6	5·53	6	·13	
156	... ...	861	7·8, 8·2, 8·2	3 42	30 45 55	322·5	3	1·5	3	·16	
157	... ...	867	7, 8	4 40	17 24 15	159·2	2	2·6	2	·16	
158	... ...	880	8, 8	8 50	10 37 1	56·76	5	5·68	5	·13	
159	... ...	878	7·2, 11	10 13	62 27 24	329·3	3	19·4	3	·16	
160	P. VI. 58	891	7·7, 10·7	12 57	12 20 33	295·0	5	20·8	5	·16	
161	... ...	901	7·7, 9·5	18 23	10 34 58	249·5	5	20·2	5	·16	
161*	... ...	906	8, 9·2	20 34	37 27 17	335·53	5	6·4	5	·13	
162	Aurigæ, 229 B ...	918	6·7, 7·7	24 21	52 33 9	323·5	5	4·5	5	·11	
163	11 Monocerotis ...	919	5, 5·5, 6	23 0	− 6 57 22	131·5	5	7·2	5	73·98	
164	20 Geminorum. H iv. 46	924	6, 7	25 18	17 52 7	211·06	5	20·4	5	74·13	

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Decl. 1880.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Remarks.
				h m s	° ′ ″	°		″			
	ζ Cancri—*continued* ...	1196	5, 5·5, 7·5	8 5 19	18 0 42	154·7	6	0·5	est.	73·32	Not good.
						144·0	5	0·6	"	·94	Good night.
						141·1	4	0·4	"	74·10	
						139·2	4	0·5	"	·16	
	AC	...	...	...	...	132·7	6	5·1	4	·10	
						133·0	5	5·7	5	·16	
207	P. VIII. 13 Cancri ...	1202	8, 10	6 59	11 12 42	325·5	5	2·1	5	·10	
208	... ...	1212	8, 10	10 35	31 12 15	236·1	4	5·2	4	·18	
209	... ...	1216	7, 7·5	15 15	− 1 13 12	167·0	6	0·5	est.	·18	Difficult and uncertain.
210	υ Cancri	1224	6, 7	19 32	24 55 48	41·2	4	5·9	4	·18	
211	... ...	1228	8, 8·5	20 22	27 57 23	350·5	5	9·4	5	·18	
212	... ...	1230	8, 10	21 38	17 14 57	193·0	4	30·8	4	·18	
213	... ...	1264	9, 9	36 24	− 7 58 16	270·2	4	5·8	5	·18	
214	... ...	1263	7, 7·5	37 16	42 8 12	19·0	1	34·9	1	·22	Not good.
215	ε Hydræ	1273	4, 9	40 26	6 51 37	216·2	3	3·4	4	·09	Violent motion.
216	Lyncis 130 B ...	1282	7, 7	43 13	35 30 43	278·0	5	4·5	5	·22	
217	σ^4 Cancri	1298	6, 8	54 3	32 43 17	137·7	4	4·7	4	·18	
218	... ...	1300	9, 9·5	54 38	15 44 59	204·0	4	4·6	4	·18	
219	... ...	1306	6·3, 9·5	59 51	67 37 22	247·2	5	2·9	4	·18	
220	... ... AB	1316	8, 11, 10	9 1 56	− 6 39 7	143·0	3	6·3	4	·18	
221	... ...	1317	8, 10	2 35	15 43 37	63·0	2	7·3	2	·20	Uncertain.
222	... ...	1322	8, 8	5 59	17 1 5	54·0	5	1·8	5	·20	
223	... ...	1321	7·4, 7·4	6 23	53 12 43	57·0	2	20·0	2	·22	Uncertain.
224	38 Lyncis	1334	4, 6·7	11 23	37 18 45	238·6	4	2·92	4	·18	
225	... ... AB	1331	8, 8, 11·5	11 24	61 51 18	154·0	3	1·0	est.	·17	Could not see C well.
226	157 B Lyncis ...	1338	6·7, 7·2	13 28	38 41 49	147·0	4	1·7	4	·18	
227	... ...	1341	8·5, 8·5	14 21	51 6 50	267·0	4	20·0	2	·26	
228	21 Ursæ Majoris. H ii. 73	1346	7, 8	17 8	54 31 58	312·0	4	5·3	2	·26	
229	... ...	1345	8·5, 10·1	17 15	64 51 37	88·0	2	2·8	2	·26	Bad discs.

233	Hydræ 134 B ...	1365	7, 8	25 20	1 59 42	155·5	5	3·[illegible]	[illegible]		
234	... ...	1362	7, 7	26 30	73 37 3	131·0	4	5·4	4	·22	
235	P. IX. 161 Sextantis ...	1377	8, 11	37 13	3 10 34	141·1	4	3·7	4	·20	Small star exceedingly [faint.
236	... ...	1404	9, 9	58 11	− 1 6 38	294·0	4	6·0	4	·20	
237	γ Leonis	1424	3, 4·5	10 13 20	20 27 2	110·7	5	3·11	5	70·30	
						113·0	4	3·1	6	71·32	
						111·0	6	3·0	5	·41	
						110·9	5	...	...	73·30	
						112·6	5	3·7	3	74·12	
237	145 B Leonis. H ii. 43 AC	1426	8. 7·5, 9	14 15	7 2 7	11·0	2	7·0	2	·22	Did not see close com- [panion.
238	P. X. 67. H i. 29 ...	1431	8, 9·7	19 16	9 23 9	61·5	5	3·0	5	·26	
239	... ...	1439	8, 8·5	23 32	21 25 7	121·0	2	2·0	2	·22	Uncertain.
240	49 Leonis	1450	6·3, 9·5	28 44	9 16 14	156·6	4	2·8	4	·20	
241	... ...	1454	8, 10	31 30	27 13 59	310·3	4	3·0	2	·21	
242	... ...	1457	7·3, 7·8	32 28	6 21 29	311·9	4	1·0	2	73·20	
243	172 B Ursæ Majoris ...	1460	8, 8	33 35	42 46 38	167·2	4	3·27	4	74·21	
244	... ...	1465	8·5, 8·8	36 10	45 15 24	5·0	2	2·0	2	·26	Bad definition.
245	... ...	1467	8, 10·7	38 13	45 35 58	288·5	2	4·0	2	·26	" "
246	... ...	1474	7, 8·8	41 43	−14 37 42	197·1	4	6·7	5	·18	
247	... ...	1476	7·5, 8·2	43 12	− 3 23 21	358·0	5	2·5	4	·21	Bad night.
248	... ...	1478	8, 11	44 33	25 5 16	349·1	4	9·2	4	·21	Boiling and dancing.
249	54 Leonis	1487	5, 7	49 7	25 23 24	104·6	4	6·5	4	·21	Discs swing about.
250	... ...	1496	8, 10	51 59	13 55 16	352·0	4	20·3	3	·22	
251	... ...	1500	7, 8	53 55	− 2 49 46	314·2	5	1·42	4	·22	
252	... ...	1502	8·5, 9	55 42	15 15 51	284·0	4	13·1	3	·22	
253	P. X. 229	1504	7·5, 7·5	57 48	4 17 6	283·9	4	1·2	3	·22	
254	... ...	1512	8, 8·5	11 1 51	63 8 49	51·0	4	9·2	5	·29	
255	... ...	1516	7, 7	7 26	74 7 24	270·5	4	9·1	4	·13	
256	P. XI. 9	1517	7·3, 7·3	7 24	20 47 16	283·5	4	1·3	4	·22	
257	ξ Ursæ Majoris ...	1523	4, 5	11 48	32 12 45	59·3	5	1·4	6	70·22	No definition.

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Decl. 1880.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Remarks.
				h m s	° ′ ″	°		″			
293	P. XIII. 127 Virginis ...	1757	7·5, 8·2	13 28 10	0 18 3	65·4	6	1·98	5	74·22	
						63·2	5	2·1	5	70·15	
						63·0	6	2·3	5	70·21	
						63·5	5	2·1	5	71·18	
						63·5	5	2·0	4	·32	
294	84 Virginis	1777	6, 8	37 3	4 8 47	231·7	5	3·52	5	·32	
295	... ...	1781	7·8, 8·2	40 5	5 43 7	256·0	5	1·1	5	·32	
296	... ...	1785	7, 7·4	43 38	27 34 52	204·1	5	2·46	5	·32	
						199·0	4	2·6	4	70·21	
						199·0	4	2·4	4	·55	
						199·8	11	2·7	11	71·32	
297	P. XIII. 238 ...	1788	6·5, 7·4	48 41	− 7 28 4	69·6	6	2·58	5	·32	
298	... ...	1796	9, 10	55 16	37 33 1	193·9	5	2·48	5	·32	
299	76 B Boötis ...	1804	8, 9	14 2 39	21 45 56	19·7	5	4·5	5	·32	
300	... ...	1813	8, 8	7 24	5 57 48	192·7	2	5·2	2	·32	
301	... ...	1816	7, 7	8 34	29 40 1	79·8	5	1·6	4	·32	
302	... ...	1819	8, 8	9 18	3 41 18	24·7	6	1·4	4	·42	
						25·7	4	1·2	4	70·32	
						26·7	4	1·27	6	·34	
						26·3	6	1·22	4	·43	
						26·2	5	1·32	5	71·24	
						27·0	3	1·4	3	·32	
						25·1	4	1·34	4	·36	
303	Boötis 121 B ...	1825	8·5, 9·5	10 59	20 40 59	180·1	2	4·2	2	·22	
304	... ...	1830	8·5, 9	11 52	57 13 48	286·4	2	5·7	3	·32	
305	... ...	1834	7, 7	15 54	49 3 26	115·3	5	0·6	3	·53	Distance very uncertain.
306	P. XIV. 69	1835	5·5, 6·8	17 29	8 59 35	186·0	2	6·0	2	·22	
307	P. XIV. 70	1837	7. 9	18 14	−11 7 26	313·0	2	1·41	2	·40	Bad sky.
308	... ...	1842	9, 9	20 57	4 13 51	13·7	2	2·9	2	·40	

309	φ Virginis	1846	5, 10	22 2	− 1 41 23	114·0	4	3·7	4	74·53	
310	... ...	1850	6, 7	23 16	28 49 36	263·6	5	25·5	3	·36	No clock driving.
311	... ...	1863	7, 7	34 1	52 5 47	93·4	3	0·5	est.	·36	
312	π Boötis	1864	3·5, 6	35 5	16 55 56	101·2	2	6·2	2	·36	
313	ζ Boötis	1865	3·5, 4	35 25	14 14 36	308·2	5	1·38	5	·36	
314	260 B Boötis ...	1867	8, 8	35 39	31 48 27	18·5	4	1·5	4	·54	Unsteady images.
315	... ...	1866	8, 8	35 54	10 2 23	22·4	4	1·0	4	·53	
316	ε Boötis. H i. 1. ...	1877	3, 7	39 45	27 34 46	327·0	4	2·9	4	·54	
317	... ...	1876	8, 8	40 1	− 6 52 48	69·1	2	1·3	2	·54	
318	... ...	1883	7, 7	42 56	6 27 29	262·2	3	1·1	3	·54	
319	286 B Boötis ...	1884	6, 8	43 4	24 51 53	55·7	5	1·4	4	·36	
						54·0	4	1·27	4	·54	
320	39 Boötis	1890	6, 7	45 37	49 12 44	45·0	2	3·6	2	·22	
321	ξ Boötis	1888	3·5, 6·5	45 51	19 35 57	289·2	5	5·0	2	·22	
322	18 Libræ	1894	6, 10	52 24	−10 39 37	39·8	4	20·3	4	·54	
323	44 Boötis	1909	5, 6	59 52	48 7 15	240·0	4	4·69	7	70·32	
						239·0	5	4·86	4	71·13	
						239·9	5	4·5	5	74·22	
324	... ...	1910	7, 7	15 1 46	9 41 11	212·7	4	4·2	3	·44	
325	... ...	1934	8·5, 8·5	13 10	44 14 5	36·2	5	6·27	3	·49	Doubtful in distance.
326	1 B Coronæ... ...	1932	6, 6·5	13 12	27 16 29	298·9	4	1·2	4	·49	
327	η Coronæ	1937	6, 6·5	18 14	30 43 31	44·6	11	1·1	10	70·44	
						45·9	5	0·9	5	71·50	
						47·0	4	1·0	4	·63	
						55·0	5	1·0	5	73·60	
						54·0	7	0·85	5	·47	
						52·2	7	...	...	·50	
						55·9	10	1·16	10	·52	
						53·5	8	...	...	·51	Much motion.
						58·8	10	1·10	10	74·36	
						58·0	10	1·07	10	·32	
						59·0	2	0·8	2	·49	
328	μ^2 Boötis. P. XV. 74 ...	1938	8, 8·5	19 59	37 45 59	152·0	10	0·46	est.	73·47	

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					h m s	° ′ ″	°		″			
	μ^2 Boötis—*continued*	...	1938	8, 8·5	15 19 59	37 45 59	152·7	5	0·5	5	73·48	
							150·68	10	0·58	10	74·22	
							150·58	12	0·5	10	·26	
							164·0	5	...	...	70·44	
							158·4	4	0·5	est.	71·65	
329	17 B Coronæ	...	1950	7, 8	24 50	25 55 14	93·4	5	3·42	5	·36	
330	δ Serpentis ...	...	1954	3, 5	29 4	10 56 23	193·0	5	2·9	5	·22	
331	... ...	...	1957	8, 9·5	30 13	13 18 52	152·5	3	1·4	3	·49	Doubtful; bad sky.
332	ζ Coronæ. H ii. 8	...	1965	4, 6·5	34 52	37 1 31	302·0	5	6·38	4	·36	Restless discs.
333	σ Coronæ Borealis.	H i. 3	2032	5, 6·1	16 10 12	34 9 48	196·0	5	3·2	5	70·22	
							197·7	6	3·5	6	·55	
							196·0	6	3·25	5	71·20	
							198·0	5	3·0	5	·63	
							195·6	4	3·6	5	·50	
							198·9	4	3·4	3	73·68	
334	ξ Libræ ...	...	1998	4·5, 5	15 57 46	−11 2 31	182·8	4	1·15	3	·49	
							168·2	5	...	...	70·21	
							174·0	5	1·0	5	71·49	
							176·5	2	1·1	3	73·68	
335	α Scorpii ...	...	...	1, 8	16 22 3	−26 9 54	268·4	10	3·29	5	·62	
							267·6	8	3·32	6	·63	
336	71 B Herculis	...	2052	7·5, 7·5	23 37	18 39 34	102·6	4	2·79	4	74·49	
							103·5	8	2·50	6	·52	
337	... ...	...	2051	7, 9	23 44	10 51 22	19·0	4	13·6	2	·42	
338	λ Ophiuchi ...	...	2055	4, 6	24 52	2 14 52	28·2	7	1·6	7	70·44	
							27·9	4	1·7	5	71·32	
							29·0	5	1·5	5	·63	
							30·0	4	1·5	3	73·68	
							33·5	10	1·26	10	74·62	

						33·2	10	1·31	10	74·63	
339	... ...	2072	8·5, 9·5	32 9	47 55 38	182·9	10	4·48	6	·49	
						182·5	10	4·6	10	·62	
340	159 B Draconis ...	2076	9, 10	34 32	0 5 50	325·5	8	8·87	9	·51	
						325·5	10	8·77	10	·63	
341	ζ Herculis	2084	3, 6	36 48	31 48 52	153·8	5	0·75	10	·51	
						157·3	8	0·81	7	·63	
342	η Herculis	2093	3, 10	38 47	39 9 6	262·4	12	116·9	5	·51	Distance difficult and [uncertain.
						262·2	8	116·7	8	·63	„ „
343	46 Herculis... ...	2095	7, 9	40 19	28 34 35	163·1	5	5·2	4	·40	
344	19 Ophiuchi. H iv. 123	2096	6, 9·3	41 7	2 16 51	90·5	3	23·0	3	·51	
345	21 Ophiuchi ...	...	6·5, 8	45 20	1 25 15	166·7	6	1·2	5	·40	No steadiness.
346	... ...	2106	6, 8	45 24	9 36 54	310·9	4	0·5	est.	·40	
347	167 B Herculis ...	2107	6·5, 8·5	47 5	28 51 59	200·3	5	0·5	„	70·55	
						203·0	5	0·5	„	71·70	
						208·4	10	0·78	10	74·63	Fair night.
						208·1	8	0·84	4	·66	
348	19 Draconis ...	2118	6, 7	55 20	65 19 2	302·4	6	0·48	est.	·66	
						303·8	6	0·5	„	·69	
349	P. XVI. 270 ...	2114	7, 8	56 13	8 37 30	152·2	10	1·6	7	·66	
						153·2	6	1·3	8	·69	
350	210 B Herculis ...	2120	6·5, 9	17 0 0	28 15 20	264·0	7	3·8	6	70·60	
						263·2	5	3·6	5	71·21	
						263·4	5	3·8	5	·50	
						259·2	4	4·1	3	73·68	
						258·6	10	4·0	9	74·66	
						258·5	10	4·0	8	·69	
351	μ Draconis	2130	4, 4·5	2 51	54 37 38	172·2	9	2·9	8	·66	
						172·6	7	2·97	6	·69	
						172·4	3	2·9	3	·70	
352	36 Ophiuchi ...	...	4·5, 6·5	7 55	−26 24 43	208·4	4	3·7	4	·66	Violent motion.
353	α Herculis	2140	3, 6	9 11	14 31 36	115·9	8	4·57	10	·66	Unsatisfactory definition.
						115·6	4	4·65	4	·69	

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Decl. 1880.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Remarks.
				h m s	° ′ ″	°		″			
	α Herculis—*continued* ...	2140	3, 6	17 9 11	14 31 36	115·2	6	4·59	5	74·70	
354	... ...	2156	8, 9	17 47	− 0 43 22	34·71	8	3·32	7	·51	
						35·40	9	3·37	6	·62	
355	P. XVII. 94 Ophiuchi ...	2160	5·5, 10	19 9	15 42 54	66·7	3	3·97	2	·70	
356	ρ Herculis	2161	4, 5·5	19 33	37 15 22	312·0	9	4·00	8	·70	
357	281 B Herculis ...	2165	7, 8·5	21 35	29 33 33	53·4	10	7·72	6	·69	
						53·5	6	7·6	5	·70	
						53·5	4	7·6	4	·72	
358	... ...	2173	6, 7	24 14	− 0 57 39	330·9	10	0·7	3	·51	
						331·7	7	0·99	6	·63	
						336·2	5	0·9	4	70·24	
						336·7	4	0·8	3	·46	
359	P. XVII. 147 ...	2180	7, 7	26 5	50 57 47	264·7	10	2·98	8	74·73	Much agitation.
						264·8	8	2·99	6	·79	
						265·0	3	3·11	3	·80	
360	315 B Herculis ...	2192	7·5, 10	35 24	29 18 14	72·51	10	10·54	4	·51	
						73·43	8	10·25	5	·63	
						73·75	...	10·5	2	·69	
361	P. XVII. 200 Herculis ...	2194	6·5, 9	36 10	24 34 17	9·85	9	16·68	7	·79	
						9·80	8	16·64	8	·80	
362	... ...	2199	7, 8	36 24	55 49 29	100·8	10	1·51	8	·73	
						100·7	6	1·47	6	·79	
						100·9	5	1·5	5	·80	
363	61 Ophiuchi ...	2202	5·5, 6	38 33	2 37 51	93·6	10	20·88	8	·51	
						93·5	8	20·81	6	·63	Very bad air.
364	μ^1 Herculis. H iv. 41 ...	2220	3·8, 10	41 47	27 48 4	100·0	10	0·4	est.	·63	
						101·0	6	0·4	„	·66	
365	337 B Herculis ...	2224	7, 10	42 1	39 22 4	350·9	10	7·6	5	·51	
						350·5	7	7·28	6	·65	

366	... ...	2234	9, 9	46 17	− 7 56 21	200·5	8	16·4	6	74·72	
367	300 P. XVII. Herculis ...	2245	7, 7	51 8	18 20 40	296·3	5	2·6	4	·51	
						296·7	8	2·6	6	·63	
368	... ...	2252	8, 8	52 58	2 2 54	25·5	4	3·9	4	·51	
369	... ...	2254	8, 9	53 27	12 26 56	267·7	8	3·29	10	·66	
						267·0	6	3·16	7	·79	
370	... ...	2258	8·5, 8·5	53 35	48 38 6	222·1	9	2·22	8	·79	
								2·27	8	·80	
371	95 Herculis ...	2264	5, 5	56 25	21 35 46	261·4	6	6·4	5	·79	
372	τ Ophiuchi	2262	5, 6	56 33	− 8 10 46	247·6	5	1·70	8	70·32	
						247·0	8	1·50	7	71·73	
						249·6	4	1·60	3	73·60	
						248·5	10	1·66	10	74·80	
373	70 *p* Ophiuchi ...	2272	4·5, 7	59 23	2 32 35	94·7	8	4·6	7	70·30	
						93·2	7	4·3	6	·72	
						92·9	5	4·4	5	71·50	
						93·1	5	4·4	5	·63	
						92·1	5	4·08	5	·80	
						89·5	6	3·90	6	73·51	
						87·5	10	3·92	5	74·73	
374	... ...	2268	8, 9	58 20	25 21 40	215·2	9	18·3	10	·73	Unsteady.
375	P. XVII. 362 Tauri Poniat.	2276	8, 8·5	18 0 8	11 59 38	259·0	8	6·71	8	·79	
						258·7	6	6·58	5	·80	
376	100 Herculis. H iii. 41	2280	7, 7	2 59	26 4 44	182·9	9	14·36	8	·62	
						183·6	6	13·98	4	·36	
377	73 Ophiuchi ...	2281	6, 7·5	3 36	3 58 22	254·4	8	1·06	6	·73	
378	417 B Herculis ...	2289	6·5, 7·5	4 47	16 27 14	237·6	7	1·15	9	·69	
379	... ...	2298	8·5, 8·5	8 51	41 21 8	182·4	9	2·58	8	·79	
						177·7	8	2·23	7	·80	Definition bad.
380	... ...	2310	7, 10	15 37	22 44 38	237·6	9	5·26	9	·84	
						237·7	9	5·23	8	·85	
381	59 Serpentis ...	2316	6, 7·5	21 4	0 7 28	315·78	10	3·59	9	·79	
						315·50	10	3·56	8	·80	

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Decl. 1880.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Remarks.
				h m s	° ′ ″	°		″			
382	... ...	2330	7, 9	18 25 41	13 5 55	173·6	10	19·41	9	74·79	
						173·5	9	19·46	5	·80	
383	55 B Tauri Poniatowski	2342	6, 8·5	29 41	4 50 29	9·3	11	28·62	11	·79	
384	... ...	2346	7·5, 9	31 26	7 25 50	289·68	10	19·34	10	·79	
385	α Lyræ	...	1, 11	32 52	38 40 4	154·0	6	...	...	73·79	Bad sky.
						153·8	10	48·5	10	74·79	
						153·8	9	48·61	10	·80	
						153·7	4	48·5	6	·85	
386	... ...	2356	8·5, 9	33 40	28 35 34	55·4	10	1·18	10	·80	
387	... ...	2360	7·5, 8·5	34 11	20 49 32	2·78	10	2·68	10	·84	
388	P. XVIII. 151 Lyræ ...	2362	8, 9	34 12	35 56 53	181·28	4	4·23	5	·79	
389	5 Aquilæ	2379	7, 8	40 17	− 1 5 16	121·6	8	13·35	9	·79	C too faint to-night.
390	H ε¹ 4 Lyræ ...	2382	5, 6·5	40 22	39 32 36	17·0	6	...	...	73·48	
						18·4	8	...	...	·81	
						18·5	5	3·1	6	·50	
	5 Lyræ	2383	5, 5·5	...	...	141·2	7	...	...	·48	
						142·1	6	2·5	6	·81	
391	... ...	2394	9, 9	41 32	41 57 9	203·0	11	6·24	11	74·84	
392	... ...	2402	8, 8·5	44 5	10 32 21	203·2	6	0·97	5	·73	
393	... ...	2424	6, 9	53 34	13 27 51	257·4	5	17·5	4	·73	
394	... ...	2426	7, 8	54 25	12 43 26	259·3	6	16·3	4	·73	
395	P. XVIII. 287 ...	2438	7, 7·5	55 30	58 3 34	330·0	2	0·5 est.	...	·73	Difficult.
396	... ...	2436	7, 8	56 24	8 34 51	309·6	11	34·17	11	·73	
397	... ...	2434	9, 9	56 34	− 0 52 43	133·2	6	23·8	4	·73	
398	... ...	2437	7·5, 7·5	56 38	18 59 49	67·9	11	1·02	10	·73	
399	P. XVIII. 302 ...	2446	7·5, 9	59 56	6 22 4	154·2	9	10·16	9	·73	
400	... ...	2455	7·5, 8·5	19 1 47	21 59 22	109·5	10	3·30	10	·73	
401	P XIX. 8 Lyræ ...	2469	7·5, 9·5	3 42	38 44 16	121·7	3	1·42	3	·84	
402	P. XIX. 13 Lyræ ...	2472	8·5, 9·5	4 24	37 43 10	339·4	4	17·2	4	·84	

403	... ...	...	2484	7·5, 9	8 59	18 51 31	232·5	4	2·51	9	74·84	
404	6 B Cygni ...	...	2486	6, 6·5	9 0	49 37 19	221·4	10	10·2	8	·84	
405	23 Aquilæ ...	...	2492	5·5, 9·5	12 26	0 52 1	13·0	3	3·2	4	·60	
406	... ...	...	2509	7, 8	15 42	62 59 22	341·86	10	1·0	8	·84	
407	... ...	...	2523	7·4, 7·5	21 37	20 55 18	151·7	4	6·4	7	·60	
408	22 B Cygni ...	...	2525	7, 7	21 40	27 4 40	234·28	10	0·48	9	·84	
409	P. XIX. 149	...	2534	8, 8	23 22	36 17 2	64·1	10	7·29	10	·84	
410	... ...	AB	2538	8, 8, 9	27 3	36 27 2	233·86	5	48·70	7	·85	
		BC	...	...	...	...	66·60	4	6·04	4	·85	Distance difficult and [uncertain.
411	P. XIX. 169	AB	2539	9, 11	27 16	28 0 39	3·2	4	5·5	2	·70	
412	... ...	AC	2544	7, 9·5, 11	31 19	8 2 48	240·0	5	16·0	5	·84	
		AB	...	...	...	...	205·2	4	0·42	4	·84	C is very faint.
413	... ...	...	2548	8, 9	31 28	24 44 0	102·0	10	10·04	6	·84	
							101·9	5	10·14	5	·85	
414	P. XIX. 186	...	2545	6·5, 8·5, 11	32 8	−10 25 37	316·66	6	3·64	5	·84	Could not get a measure of C.
							316·6	3	3·85	3	·85	
							316·7	4	3·71	4	·85	
415	... ...	...	2576	7·5, 7·7	41 0	33 19 53	305·7	9	3·48	5	·85	
							305·3	5	3·25	5	·85	
416	17 χ Cygni ...	...	2580	5, 8	41 52	33 27 16	72·6	8	26·0	6	·85	Distance difficult.
417	π Aquilæ ...	...	2583	6, 7	43 3	11 31 1	121·63	8	1·52	8	·85	Bad definition.
							121·1	6	1·45	6	·85	
418	ζ Sagittæ ...	...	2585	5, 9	43 39	18 50 26	310·2	6	9·0	3	·85	
419	α Aquilæ ...	...	...	1·5, 10	44 54	8 32 46	313·0	3	157·0	3	·70	
420	ε Draconis ...	...	2603	5·5, 9	48 34	69 57 43	0·88	8	3·15	5	·84	
							0·58	6	3·19	4	·85	
421	ψ Cygni ...	...	2605	5·5, 8	52 32	52 7 14	183·4	8	3·83	8	·85	
							183·58	8	3·63	8	·85	
422	... ...	...	2624	7, 8	59 1	35 41 14	176·0	8	1·95	8	·91	
							175·7	8	1·83	7	·91	
423	... ...	...	2640	7, 11	20 3 14	63 32 39	20·3	4	4·7	3	73·79	
424	... ...	...	2644	7, 7·2	6 28	0 30 32	208·0	5	3·4	3	·79	
425	... ...	...	2666	6·5, 8·5	13 52	40 21 28	248·5	9	2·86	9	·91	

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Decl. 1880.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Remarks.
				h m s	° ′ ″	°		″			
425	*continued*	2666	6·5, 8·5	20 13 52	40 21 28	246·1	8	2·97	8	73·91	
426	176 B Cygni ...	2668	7, 9	15 54	39 1 30	291·5	9	2·98	9	·91	
						292·5	8	3·11	8	·91	
427	... ...	2673	8, 9·5	17 6	12 57 27	330·3	6	2·0	3	·91	
428	178 Delphini. P. XX. 178	2690	7·5, 8	25 29	10 51 24	255·0	4	15·1	4	·91	Could not see C.
429	... ...	2696	8, 8·5	27 35	5 2 2	304·4	8	0·87	8	·91	
						303·9	7	0·80	7	·91	
430	... ...	2708	7, 8·3	34 8	38 13 20	335·0	8	21·4	7	·91	
431	49 Cygni	2716	6, 8	36 11	31 52 50	52·0	3	3·2	3	·91	
432	52 Cygni	2726	5·5, 9·5	40 43	30 16 52	61·5	4	6·7	3	·91	
433	γ Delphini	2727	4, 5	41 6	15 41 40	272·2	8	11·36	7	·91	
434	P. XX. 376 Equulei ...	2735	6, 8	49 40	4 4 27	288·3	4	2·01	4	·91	
435	ε Equulei	2737	5·5, 7·5	53 5	3 50 7	287·0	4	1·10	4	·91	
436	P xx. 429	2741	6, 7·5	54 39	49 59 43	33·7	8	1·89	9	·91	
437	... ...	2744	6·3, 7·1	56 58	1 3 39	176·2	4	1·5	4	·91	
438	12 Aquarii	2745	5·5, 8·5	57 44	− 6 17 52	192·0	4	3·2	3	·91	
439	61 Cygni	2758	5·5, 6	21 1 14	38 6 52	113·8	6	19·12	7	70·20	
						113·9	6	19·38	6	·63	
						114·0	6	19·0	5	70·80	
						114·1	6	19·18	5	71·32	
						114·0	6	19·32	6	·73	
						113·9	6	19·20	4	73·73	Unsteady.
						116·1	4	...	...	·68	
						115·9	3	...	...	·81	
						115·0	4	19·5	3	·70	
						115·2	10	19·46	8	74·91	
						115·6	8	19·6	8	·91	
440	... ...	2760	7, 8	1 53	33 39 7	225·3	4	9·42	3	·70	
441	... ...	2762	6·5, 9	3 33	29 43 15	313·0	2	3·40	2	·80	No clock driving.

442	... ...	...	2767	8, 8·2	5 1	19 28 6	30·7	4	2·47	2	74·80	
443	P. XXI. 51 ...	...	2780	6·5, 7·5	8 45	59 29 33	224·7	4	0·9	4	·80	
							224·8	8	1·1	8	·91	
444	... ...	BC	2776	7, 9, 10	8 55	−10 50 49	341·0	3	5·3	2	·80	
445	... ...	...	2784	8, 10·5	11 12	73 33 46	348·2	4	14·4	3	·91	
446	20 B Pegasi ...	...	2799	6·5, 7·4	23 2	10 33 37	313·7	4	1·41	6	73·80	
447	β Cephei ...	...	2806	3, 8	27 6	70 2 2	251·4	3	13·6	3	74·91	
448	29 B Pegasi	...	2804	7, 8	27 26	20 10 57	328·5	6	3·02	4	·79	
							325·3	4	...	...	·80	
449	P. XXI. 248	AB	2816	6, 8·5	35 14	56 56 47	122·9	5	11·78	4	74·91	No clock.
450	P. XXI. 256	...	2819	8, 9	36 38	57 2 13	57·71	8	12·86	7	·91	
451	μ Cygni ...	...	2822	4·3, 7	38 45	28 12 14	117·76	5	...	...	73·80	
							117·56	8	3·89	8	74·91	
452	κ Pegasi ...	...	2824	4, 1·3	39 12	25 5 37	302·5	3	12·1	3	·80	
453	147 Cephei ...	...	2840	6, 7	47 57	55 13 58	194·9	7	20·16	9	·91	
454	... ...	...	2846	8·5, 10·3	50 7	45 13 26	280·	8	3·7	6	·91	Very difficult.
455	ξ Cephei ...	...	2863	5, 7	22 0 17	64 2 29	284·8	7	6·6	7	·91	
456	148 B Pegasi	...	2878	7·5, 9	8 30	7 22 52	130·8	9	1·217	8	·91	
457	P. XXI. 33	...	2877	6·5, 9·5	8 33	16 35 54	347·9	5	...	...	73·74	
							348·5	4	10·0	5	·79	
							351·0	3	...	...	·79	
458	... ...	...	2881	6·7, 7·3	9 6	28 57 41	105·68	9	1·70	8	74·91	No clock.
459	P. XXII. 65	...	2894	6·5, 9	13 40	37 9 56	195·8	10	15·7	10	·91	
460	... ...	...	2895	8, 9·5	15 8	24 21 11	28·76	9	6·62	9	·91	
461	33 Pegasi ...	AB	2900	6, 8, 10	17 52	20 14 31	175·16	7	1·83	5	·91	Difficult to-night.
							176·26	5	1·88	4	·91	
		AC	...	...	...	...	330·4	5	63·3	5	73·80	
							332·1	4	...	...	·80	
							331·9	5	63·3	3	74·91	
462	... ...	...	2910	8, 9	22 31	22 55 18	343·78	7	5·38	8	·91	
463	ζ Aquarii ...	...	2909	4, 4·2	22 38	− 0 38 7	335·9	5	3·27	6	70·63	
							336·8	5	3·40	6	71·70	
							336·2	4	...	...	73·73	

Ref. No.	Name of Star.	Struve's No.	Mags.	R.A. 1880.	Decl. 1880.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Date 1800 +	Remarks.
				h m s	° ′ ″	°		″			
	ζ Aquarii—*continued* ...	2909	4, 4·2	22 22 38	−0 38 7	335·9	5	3·6	4	73·74	
						336·8	3	...	...	·80	
						335·2	6	3·44	5	·87	
						334·9	9	3·6	8	74·91	
						334·9	8	3·59	8	·91	
464	37 Pegasi	2912	6, 7	23 54	3 49 26	119·6	6	0·5	est.	73·87	Very difficult.
465	... ...	2917	8, 8	25 50	52 54 47	73·2	6	4·7	10	·87	
						72·9	8	4·71	8	74·91	
466	... ...	2924	5, 6	29 33	69 17 29	266·5	8	1·14	10	·91	
467	... ...	2925	8, 9	31 50	5 17 1	2·9	5	7·5	5	73·83	
						2·5	3	7·3	4	·911	
468	... ...	2928	8, 8·3	33 10	−13 13 58	317·5	5	4·07	4	·82	Very faint.
467	... ...	2934	7·7, 9	36 3	20 48 25	163·63	6	1·16	6	·87	
468	P. XXII. 219 Aquarii AB	2944	7·7, 8	41 40	− 4 50 50	254·0	5	3·38	5	·82	
	AC	...	...	...	...	141·5	5	49·08	5	·82	
467	263 B Pegasi ...	2958	6, 9	50 51	11 12 28	9·2	6	4·10	4	·87	
468	... ...	2968	7·5, 11	53 33	30 17 0	90·93	6	2·96	5	·87	
469	... ... AC	2976	8.5, 9·8	23 1 37	5 57 20	186·0	4	16·4	5	·82	Distance uncertain.
470	P. XXII. 306 ...	2978	7, 8·5	1 43	32 10 36	144·0	2	8·7	4	·82	
471	π Cephei	...	5, 10	3 45	74 41 1	20·1	6	1·28	10	74·91	Small star not well seen [to night.
						19·5	8	1·19	6	·91	
472	... ...	2995	8, 8	10 23	− 2 14 30	28·46	5	5·0	6	73·87	Difficult.
						28·61	4	5·0	3	·91	
473	o Cephei	3001	6, 8·5	13 41	67 27 16	189·85	7	...	...	·80	
						191·0	5	...	...	·81	
						190·7	8	2·7	7	74·91	
						189·9	8	2·6	8	·91	
474	... ...	3006	8·5, 9	15 25	34 47 10	169·9	6	5·0	6	73·87	
						172 9	9	4·9	8	74·91	

475	P. XXIII. 69 Aquarii ...	3008	6·2, 7·5	17 32	− 9 7 5	249·6	5	5·16	5	73·82	
476	Cephei 287	3017	7·5, 9	22 54	73 27 27	34·5	6	2·0	5	·87	
477	... ...	3046	8, 8·3	50 14	−10 9 51	240·5	2	3·2	2	·87	Cloudy.
478	... ...	3047	8, 8·5	51 49	56 43 15	72·1	6	1·11	6	·87	
479	σ Cassiopeiæ. H i. 5 ...	3049	6, 8	52 55	55 5 14	326·0	4	3·5	5	·90	
						326·1	4	3·6	5	·91	
						327·2	2	3·5	4	·91	
						326·8	8	3·4	8	74·91	No driving clock.
480	37 Andromedæ ...	3050	5·7, 6·3	53 22	33 3 37	201·0	6	...	...	73·79	
						201·2	6	...	...	·81	
						200·7	5	...	...	·82	
						202·5	7	3·16	8	74·91	
481	... ...	3061	8, 8·2	59 35	17 10 23	147·6	4	7·5	5	73·87	
						148·5	7	7·5	6	·87	
						148·5	8	7·6	8	74·91	
482	B.A.C. 8372 ...	3062	6·5, 7·3	59 57	57 46 1	281·0	5	1·5	6	70·44	Restless.
						284·0	4	1·6	7	71·60	
						289·4	6	1·5	5	73·81	
						286·7	4	1·6	5	·87	
						291·1	8	1·4	7	74·91	No clock.
						291·0	9	1·3	8	·91	
483	... ...	3121	7·5, 7·8	9 10 44	29 6 57	210·4	5	0·5	est.	70·44	Difficult.
						212·7	4	0·5	"	71·21	
						214·5	4	0·5	"	73·70	
484	δ Herculis. H v. 1 ...	3127	3, 8·1	17 10 0	25 7 8	182·0	5	19·5	4	70·32	
						181·5	4	19·2	3	71·32	
						180·7	5	19·5	6	·63	
						181·1	2	19·0	3	73·68	

V.—*Proper Motions of* 406 *Southern Stars.* By E. J. STONE, Esq., M.A., F.R.S., Her Majesty's Astronomer, Cape of Good Hope.

THE Proper Motions contained in this paper were determined by me when forming the "Cape Catalogue of 1,159 Stars for 1860." The materials available for our determinations of the Proper Motions of the southern stars are at present poor. It is true that LACAILLE observed, at the Cape of Good Hope, in the years 1751 and 1752, the places of about 9,766 of the southern stars, and that these observations have been made available for use by their reduction and the publication of the mean places for 1750. About 398 of these stars were observed by LACAILLE with his altitude instruments, and the resulting places appear to be deserving of every confidence. But of these 398 stars only about 130 are southern stars not contained in BRADLEY'S Catalogue. The remainder of the 9,766 positions fixed by LACAILLE were determined from the times of the appearance and disappearance of the stars in the rhomboidal micrometer. To test the value of these observations I have carried back to the year 1750 the positions of a very considerable number of stars derived from recent observations, in cases where at least close approximations to the Proper Motions could be obtained, from sources independent of LACAILLE'S observations. The agreement with LACAILLE'S places is sometimes close; but the discordances are in general so large and irregular that I have felt myself compelled to abandon any hopes of obtaining satisfactory Proper Motions from a comparison between LACAILLE'S places, derived from observations with his rhomboidal micrometer, and our recent observations. I have come to this conclusion with considerable reluctance; for if these observations of LACAILLE made in 1751 and 1752 are rejected, we

have no catalogues of southern stars available earlier than Brisbane's "Catalogue of 7,385 Stars observed in the Years 1822 to 1826, and reduced to the Epoch 1825." Unfortunately, the Right Ascensions of Brisbane's Catalogue are useless for determinations of Proper Motion, and the rejection of Lacaille's observations compels us to rest our determinations of the Proper Motions chiefly upon the accurate, but somewhat limited, Catalogues of Fallows, Johnson, and Henderson, about the epoch 1830.

The Proper Motions given in the present paper result from a comparison between the 1860 Catalogue and the following earlier Catalogues:—

Brisbane.—A Catalogue of 7385 Stars, chiefly in the Southern Hemisphere, prepared from Observations made in the Years 1822, 1823, 1824, 1825, and 1826, at the Observatory at Paramatta, New South Wales. Epoch 1825.

The R.A.'s are not used for the determination of the Proper Motions.

Fallows.—Results of the Observations made by the Rev. Fearon Fallows, at the Cape of Good Hope, in the Years 1829, 1830, and 1831. Reduced under the superintendence of G. B. Airy, Esq., Astronomer Royal. (*Memoirs of the Royal Astronomical Society*, Vol. XI.)

Johnson.—A Catalogue of 606 Principal Fixed Stars in the Southern Hemisphere, deduced from Observations made at the Observatory, St. Helena, 1829 to 1833. London, 1835.

The N.P.D.'s are corrected to make the refractions used agree with the results of Bessel's Tables.

Henderson.—Mean Declinations of 172 Principal Fixed Stars for January 1, 1833, from Observations made at the Observatory, Cape of Good Hope, in the Years 1832 and 1833. Edinburgh, October 16, 1835.

Henderson.—On the Right Ascensions of the Principal Fixed Stars, deduced from Observations made at the Observatory, Cape of Good Hope, in the Years 1832 and 1833. (*Memoirs of the Royal Astronomical Society*, Vol. XV. London, 1844.)

I have also made use of an unfinished Catalogue, deduced from the observations made at the Royal Observatory, Cape of Good Hope, 1834 to

1840, under the superintendence of Sir Thomas Maclear. This Catalogue is reduced to the year 1840, and has been completed and examined by me so far as required for the present comparisons.

The intervals between the Catalogues compared are too short to give the Proper Motions with any extreme accuracy.

I consider that the third place in the Proper Motions in R.A. and two or three hundredths in the Proper Motions in N.P.D. are uncertain.

I have given the separate results of the comparison of the place of the 1860 Catalogue with each of the earlier Catalogues whenever the star is contained in more than one of these Catalogues. These separate results will indicate with some accuracy what reliance can be placed on the adopted Proper Motions, and also afford some idea of the confidence with which the results derived from only one comparison may be received.

Whenever Lacaille's observations are referred to in the notes, the reference is to the observations made with the altitude instruments.

Proper Motions of Southern Stars deduced from a Comparison of the Places of the Cape Catalogue of 1,159 Stars for 1860 with those of certain earlier Catalogues.

No.	No. in B.A.C.	Approx. R.A.	Approx. N.P.D.	Fallows R.A.	Johnson R.A.	Henderson R.A.	Cape Catalogue, 1840, R.A.	Brisbane N.P.D.	Fallows N.P.D.	Johnson N.P.D.	Henderson N.P.D.	Cape Catalogue, 1840, N.P.D.	Adopted P. Motion R.A.	Adopted P. Motion N.P.D.
		h. m.	° ′	s.	s.	s.	s.	″	″	″	″	″	s.	″
1	11	0 2	136 31	+0.010	+0.005			+0.18		+0.21		+0.18	+0.008	+0.19
2	19	0 3	173 0		−0.013	−0.001	−0.027	−0.07		−0.03	0.00	−0.01	−0.014	−0.03
*3	64	0 12	155 41		+0.268		+0.262	−1.27		−1.13		−1.15	+0.265	−1.18
†4	71	0 13	179 8			+0.012	+0.047			−0.08	0.00	0.00	+0.012	0.00
5	70	0 14	160 24					+0.04						+0.04
*6	88	0 18	168 2	+0.728	+0.710	+0.721	+0.719	−0.32	−0.36	−0.35	−0.28	−0.31	+0.720	−0.32
*7	94	0 19	133 3	+0.020	+0.018	+0.019	+0.033	+0.42		+0.39	+0.39	+0.41	+0.022	+0.40
8	127	0 25	153 43	+0.016	+0.011		−0.002	−0.01		+0.01		+0.10	+0.008	+0.03
9	134	0 26	153 48		+0.013		+0.011	−0.02		−0.03		−0.04	+0.012	−0.03
10	143	0 27	143 8				+0.035						+0.035	
11	176	0 33	150 14				+0.125	−0.66				−0.43	+0.125	−0.54
12	183	0 34	136 51		−0.009			+0.17		+0.08			−0.009	+0.12
13	265	0 49	143 56				+0.001	+0.09					+0.001	+0.09
14	317	0 59	137 28	−0.001	−0.011		−0.007	+0.09		−0.01		+0.03	−0.006	+0.04
15	333	1 1	152 31				+0.003	−0.05				+0.03	+0.003	−0.01
16	340	1 2	145 59	−0.012	−0.023		−0.029	0.00		−0.01		+0.06	−0.021	+0.02
17	380	1 8	136 16				+0.070	−0.17				−0.12	+0.070	−0.15
18	392	1 11	159 37				+0.081	−0.14				−0.10	+0.081	−0.12
19	398	1 12	157 8				+0.001	−0.04				+0.03	+0.001	−0.01
20	422	1 17	157 7				−0.017	+0.06				0.00	−0.017	+0.03
21	426	1 18	132 13		−0.001		−0.001	+0.08		+0.02		+0.08	−0.001	+0.06
22	447	1 22	134 2	0.000	−0.008	−0.005	−0.002	+0.24		+0.21	+0.24	+0.26	−0.004	+0.24
23	461	1 25	139 48	+0.016	+0.004		+0.008	−0.20		−0.11		−0.12	+0.009	−0.14
24	507	1 32	147 56	+0.015	+0.003	+0.006	+0.008	+0.07	+0.08	+0.05	+0.07	+0.07	+0.008	+0.07

* 3, 6, 7. Lacaille's observations confirm these large Proper Motions.
† 4. The adopted Proper Motions have been obtained from a more general discussion, including recent observations.

25	541	1	39	115	45	+0·013	+0008		+0·005			+0·12		+0·05	+0·009	+0·08
26	550	1	40	144	13				+0·012	0·00				−0·07	+0·012	−0·04
27	554	1	41	169	51				−0·012	−0·02				+0·05	−0·012	+0·02
28	557	1	41	173	41				+0·091	−0·06					+0·091	−0·06
29	582	1	48	136	59				−0·015	+0·17				+0·14	−0·015	+0·15
30	585	1	48	133	11		−0·014		−0·015	+0·03		+0·05		+0·04	−0·015	+0·04
31	596	1	50	142	18	+0·074	+0·059		+0·069	−0·25		−0·29		−0·22	+0·067	−0·25
32	623	1	54	152	15	+0·042	+0·025	+0·034		−0·03		+0·01	+0·01	−0·01	+0·034	−0·01
33	634	1	56	135	23		−0·004		−0·004	−0·04		+0·03		+0·06	−0·004	+0·02
34	659	2	1	145	45					+0·08						+0·08
35	688	2	6	121	22				−0·003	−0·08					−0·003	−0·08
36	717	2	11	142	9	+0·013	−0·009		+0·012	+0·06		+0·05		+0·04	+0·005	+0·05
37	756	2	19	159	17	−0·003	−0·017		−0·010	−0·03		−0·02		+0·03	−0·010	−0·01
38	763	2	21	138	20	+0·003	−0·003		−0·001	+0·03		+0·05			0·000	+0·04
39	787	2	27	136	29					−0·11						−0·11
40	820	2	32	143	9					+0·02						+0·02
41	828	2	34	133	29		+0·006			+0·05		+0·02			+0·006	+0·03
42	832	2	35	130	27		+0·005		+0·001	+0·10		+0·04		+0·05	+0·003	+0·06
43	849	2	37	158	52		+0·014		+0·021	−0·03		0·00		+0·01	+0·017	0·00
44	864	2	40	133	25				−0·002	+0·07					−0·002	+0·07
45	879	2	43	122	59		+0·010		+0·006	−0·15		−0·11		−0·11	+0·008	−0·12
46	882	2	43	158	12		+0·010		+0·020	−0·06		−0·04		0·00	+0·015	−0·03
47	911	2	49	153	28				+0·001	−0·14					+0·001	−0·14
48	937	2	52	130	52		−0·009	−0·011	−0·005	−0·08		−0·05	−0·07	−0·02	−0·008	−0·05
49	982	3	1	162	26		+0·002		0·000	−0·04		−0·02		+0·02	+0·001	−0·01
50	1044	3	14	133	36		+0·258		+0·273	−0·82		−0·70		−0·72	+0·266	−0·75
51	1056	3	16	157	26				+0·011	+0·11				+0·19	+0·011	+0·15
52	1070	3	19	167	53				+0·040	−0·04				−0·06	+0·040	−0·05
53	1109	3	28	122	20					+0·09						+0·09
54	1125	3	32	130	44	+0·004	−0·005		0·000	+0·06		0·00		+0·07	0·000	+0·04
55	1150	3	36	122	23		−0·004		−0·004	−0·01		+·004		+0·02	−0·004	+0·02
56	1159	3	37	127	45		−0·006			+0·13		+0·05			−0·006	+0·09
57	1197	3	42	155	14		+0·037		+0·050			−0·04		−0·01	+0·043	−0·03

No.	No. in B.A.C.	Approx. R.A.	Approx. N.P.D.	Fallows. R.A.	Johnson R.A.	Henderson R.A.	Cape Catalogue, 1840, R.A.	Brisbane N.P.D.	Fallows N.P.D.	Johnson N.P.D.	Henderson N.P.D.	Cape Catalogue, 1840, N.P.D.	Adopted P. Motion R.A.	Adopted P. Motion N.P.D.
		h. m.	° ′	s.	s.	s.	s.	″	″	″	″	″	s.	″
58	1199	3 43	128 3	+0·010	+0·003		+0·014	+0·03		+0·01		+0·07	+0·009	+0·04
59	1201	3 44	126 37		−0·008			+0·10		+0·04			−0·008	+0·07
60	1220	3 48	125 8		0·000		−0·006	+0·06		+0·04		+0·05	−0·003	+0·05
61	1230	3 49	164 40	+0·026	−0·004	+0·008	+0·017	−0·15		−0·13	−0·12	−0·08	+0·012	−0·12
62	1259	3 56	151 47	+0·003	−0·009		−0·007	−0·06		+0·07		+0·05	−0·004	+0·02
63	1270	3 58	152 33		−0·017		−0·013	−0·07		+0·05		+0·05	−0·015	+0·01
64	1271	3 59	151 28				+0·010	−0·08				+0·02	+0·010	−0·03
65	1299	4 6	132 21				+0·013	−0·02				+0·02	+0·013	0·00
66	1315	4 9	132 38	+0·002	−0·003		−0·002	+0·26		+0·19		+0·23	−0·001	+0·23
67	1331	4 12	141 50		+0·002		+0·006	−0·07		−0·11		−0·11	+0·004	−0·10
68	1333	4 12	124 8		+0·002		+0·003	−0·02		+0·03		+0·01	+0·002	+0·01
69	1336	4 12	152 49	+0·008	−0·002	+0·002	+0·010	−0·14		−0·06	−0·04	−0·04	+0·005	−0·07
70	1348	4 14	134 36				−0·002	+0·02				−0·09	−0·002	−0·03
71	1358	4 16	153 35		−0·007		−0·011	−0·11		+0·09		+0·10	−0·009	+0·05
72	1372	4 18	124 20	+0·011	−0·001		+0·006	−0·05		−0·01		−0·02	+0·005	−0·03
73	1383	4 20	153 43	+0·025	+0·003		+0·012	−0·24		−0·12		−0·15	+0·013	−0·17
74	1413	4 26	135 15	+0·002	−0·007		−0·014	−0·01		+0·09		+0·05	−0·006	+0·04
75	1426	4 27	170 32					−0·10				−0·12		−0·11
*76	1438	4 30	145 20	+0·017	+0·004	+0·011	+0·010	+0·07		+0·03	+0·01	+0·07	+0·011	+0·04
77	1454	4 33	171 53				−0·006	−0·24				−0·10	−0·006	−0·17
78	1458	4 36	132 7	−0·011	−0·017		−0·021	+0·10	+0·06	+0·09		+0·18	−0·016	+0·11
79	1464	4 37	127 25		−0·006		−0·005	−0·19		−0·16		−0·24	−0·006	−0·20
80	1473	4 39	140 44				+0·001	−0·02				−0·02	+0·001	−0·02
81	1483	4 41	129 36				−0·007	+0·06				−0·13	−0·007	(−0·04)
82	1506	4 45	131 33				−0·005	−0·06				−0·13	−0·005	−0·10
83	1559	4 56	116 28				+0·005	+0·10				+0·10	+0·005	+0·10
84	1587	4 59	165 9					−0·08						−0·08

* 1438. Lacaille's observations make the Proper Motion in N.P.D. insensible.

85	1573	4	59	125	40		+0·006		+0·009	+0·08		+0·11		+0·08	+0·007	+0·09
86	1574	4	59	125	54				0·000	−0·18				−0·02	0·000	−0·10
87	1650	5	12	125	2				+0·010	+0·27				+0·34	+0·010	+0·31
88	1659	5	13	157	20					−0·07				+0·00		−0·04
89	1672	5	15	140	45				+0·003	−0·09				−0·19	+0·003	−0·14
90	1704	5	19	146	16				−0·004	−0·13				−0·05	−0·004	−0·09
91	1712	5	21	142	26					−0·02				+0·10		+0·04
92	1739	5	26	125	34		+0·001		+0·003	+0·02		+0·09		+0·09	+0·002	+0·07
93	1791	5	32	152	34		−0·005		−0·002	−0·19	−0·04	+0·04			−0·003	−0·05
94	1841	5	40	122	21	−0·007	−0·004		−0·004	0·00		+0·07			−0·005	+0·04
95	1855	5	42	136	39				−0·001	−0·06				+0·05	−0·001	0·00
96	1861	5	43	141	7					−0·10				−0·01		−0·06
97	1870	5	44	168	53					−0·08				−0·08		−0·08
98	1868	5	44	155	47	+0·008	−0·009		−0·005	−0·06		+0·07		+0·04	−0·002	+0·02
99	1890	5	47	142	8				(−0·139)	+0·02				+0·12		+0·07
100	1891	5	48	123	50				0·000	−0·17				−0·01	0·000	−0·09
*101	1898	5	48	170	34					−1·13				−1·16		−1·10
102	1905	5	50	156	56		−0·008		+0·003	−0·11		(+0·07)		−0·07	−0·003	−0·09
†103	1922	5	52	125	18	−0·001	−0·008		−0·007	(−0·14)		+0·01		+0·01	−0·005	+0·01
104	1933	5	54	132	49		−0·001		+0·003	+0·01		+0·05		+0·01	+0·001	+0·02
105	1964	6	0	135	2				−0·009	−0·25				−0·19	−0·009	−0·22
106	1982	6	2	127	14		−0·006		−0·009	−0·06		+0·04		−0·02	−0·007	−0·01
107	2013	6	7	144	56				−0·006	0·00				+0·05	−0·006	+0·02
108	2096	6	20	142	37	+0·004	−0·008	−0·003	−0·002	−0·05	−0·04	−0·02	−0·03	−0·03	−0·002	−0·03
109	2119	6	23	159	54					−0·12				−0·04		−0·08
110	2137	6	26	140	8				−0·010	−0·02					−0·010	−0·02
‡111	2145	6	26	159	36					(−0·36)				−0·09		−0·09
112	2176	6	31	142	51				0·000	−0·04				+0·05	0·000	+0·01
113	2188	6	33	133	4	+0·001	−0·007		−0·006	0·00	0·00	+0·03	+0·01	+0·03	−0·004	+0·01

* 1898. The large Proper Motion in N.P.D. is confirmed by observations made in 1873, which give −0·90 when compared with the 1860 Catalogue. There is only one observation in 1840, and the year of observation is not given in Brisbane's Catalogue.

† 1922. There are twenty-eight observations of this star in N.P.D. in the 1840 Catalogue.

‡ 2145. There are four observations in Brisbane, but from the run of the recent observations, I fear an error of 10″ in Brisbane's Catalogue.

No.	No. in B.A.C.	Approx. R.A.	Approx. N.P.D.	Fallows R.A.	Johnson R.A.	Henderson R.A.	Cape Catalogue, 1840, R.A.	Brisbane N.P.D.	Fallows N.P.D.	Johnson N.P.D.	Henderson N.P.D.	Cape Catalogue, 1840, N.P.D.	Adopted P. Motion R.A.	Adopted P. Motion N.P.D.
		h. m.	° ′	s.	s.	s.	s.	″	″	″	″	″	s.	″
114	2231	6 42	127 46				−0·001	+0·06				+0·06	−0·001	+0·06
115	2252	6 45	124 12				−0·001	(−0·21)				−0·04	−0·001	−0·04
*116	2260	6 46	151 47		−0·008		−0·001	−0·29		−0·15		−0·09	−0·005	−0·18
117	2259	6 46	143 27					+0·05				−0·09		−0·02
118	2290	6 51	170 39					−0·08				−0·15		−0·12
119	2295	6 53	123 55				−0·004	−0·07					−0·004	−0·07
120	2327	6 59	132 7				−0·007	−0·15				−0·06	−0·007	−0·11
121	2355	7 4	129 25		−0·007		−0·009	+0·05		+0·06		+0·03	−0·008	+0·05
122	2380	7 7	130 15				−0·010	+0·06				+0·04	−0·010	+0·05
123	2414	7 12	126 50		−0·003		−0·005	+0·01		+0·06		−0·01	−0·004	+0·02
124	2427	7 13	128 57				−0·018	−0·09				+0·12	−0·018	0·00
125	2447	7 16	157 42		−0·004			−0·02		+0·03			−0·004	0·00
126	2482	7 24	133 1	+0·008	−0·001		+0·008	−0·16		−0·06		−0·06	+0·005	−0·09
127	2484	7 25	120 40					−0·04						−0·04
128	2562	7 38	118 37		−0·002		−0·001	+0·09		+0·04		+0·02	−0·002	+0·05
129	2580	7 40	127 37	+0·002	−0·002		0·000	+0·02		0·00		−0·02	0·000	0·00
130	2594	7 42	115 35				−0·004	+0·07				−0·07	−0·004	0·00
131	2620	7 44	136 1	−0·001	−0·003			−0·12		+0·04		+0·03	−0·002	0·00
132	2629	7 47	124 21				−0·019	−0·34				−0·30	−0·019	−0·32
133	2642	7 49	139 15					−0·02						−0·02
134	2644	7 49	137 44		−0·002			−0·10		−0·04			−0·002	−0·07
135	2665	7 53	142 36	+0·006	−0·003	0·000	+0·003	−0·07	+0·01	+0·06	+0·03	+0·08	+0·001	+0·02
136	2670	7 54	138 52					−0·02				+0·07		+0·02
137	2710	7 58	129 36	−0·001	−0·008	−0·003		−0·03	−0·07	−0·01	−0·05	+0·01	−0·004	−0·03
138	2755	8 5	136 55	+0·007	−0·002	+0·002		+0·05		+0·04	+0·03		+0·002	+0·04
139	2773	8 7	158 12		−0·015			−0·13		0·00			−0·015	−0·06

* 2260. The observations of Lacaille appear to agree with Brisbane's place better than with that of the 1840 Catalogue.

140	2774	8	8	125	28				−0·004					+0·02	−0·004	+0·02
141	2795	8	13	126	13	−0·015	−0·018		−0·017	−0·15		−0·05		−0·12	−0·017	−0·11
142	2823	8	18	138	2				−0·007	−0·07				+0·04	−0·007	−0·01
143	2832	8	19	149	3	−0·005	−0·019	−0·014	−0·017	−0·10	−0·04	−0·02	−0·04	+0·02	−0·014	−0·03
*144	2878	8	20	178	27			−0·016	0·000				−0·01	−0·02	−0·014	−0·02
145	2849	8	22	166	28		+0·028		+0·019	−0·11		−0·10		−0·15	+0·024	−0·12
146	2856	8	23	162	56		−0·022			−0·13		−0·01		+0·08	−0·022	−0·02
147	2863	8	24	155	40	−0·001	−0·018			+0·06		+0·13		+0·17	−0·009	+0·12
148	2870	8	24	167	1		−0·045			−0·04		+0·02			−0·045	−0·01
149	2926	8	32	132	30					+0·05				0·00		+0·02
150	2947	8	35	136	9		−0·006			−0·04		+0·07		+0·04	−0·006	+0·02
†151	2950	8	36	142	25		+0·001		+0·001	−0·11		+0·07		−0·02	+0·001	(−0·02)
152	2962	8	37	149	15					−0·09		+0·05		+0·11		+0·02
153	2979	8	40	144	11	−0·001	−0·009	−0·006		+0·04	+0·10	+0·11	+0·10	+0·10	−0·005	+0·09
154	2981	8	41	135	31		−0·009			−0·06		−0·03		−0·02	−0·009	−0·04
155	2998	8	43	146	15					−0·03				+0·08		+0·02
156	3023	8	45	168	27		−0·022		−0·004	−0·05		+0·01		−0·03	−0·013	−0·02
157	3073	8	53	148	41	+0·003	−0·007			−0·14		+0·07		−0·05	−0·002	−0·04
158	3089	8	55	148	32	0·014	−0·025			−0·33		−0·18		−0·22	−0·020	−0·24
159	3110	8	59	136	32		−0·019		−0·017	−0·19		−0·09		−0·15	−0·018	−0·14
160	3126	9	2	132	52	−0·005	−0·006	−0·005	−0·006	−0·01	0·00	+0·01	0·00	+0·01	−0·006	0·00
‡161	3136	9	4	162	2		−0·033			−0·10		0·00		+0·04	−0·033	−0·02
162	3152	9	8	151	44		−0·019			−0·04		0·00		+0·03	−0·019	0·00
163	3163	9	10	127	59				−0·015	+0·11				+0·05	−0·015	+0·08
164	3177	9	11	159	8	−0·027	−0·039	−0·033	−0·030	−0·14	−0·07	−0·09	−0·08	−0·08	−0·032	−0·09
165	3186	9	13	148	41	+0·005	−0·009	−0·004	−0·006	−0·05		+0·07	+0·01	+0·04	−0·003	+0·02
166	3187	9	13	140	27				−0·006	−0·10				+0·07	−0·006	−0·02
167	3211	9	16	175	5				−0·069	−0·03				+0·02	−0·069	−0·01
168	3213	9	17	144	24	−0·001	−0·014	−0·005		−0·06		+0·02	−0·01	+0·03	−0·007	−0·01
169	3257	9	25	129	51		−0·023		−0·031	−0·09		−0·02		−0·09	−0·027	−0·07
170	3269	9	26	146	25		−0·018		−0·011	0·00		+0·01		+0·02	−0·015	+0·01

* 2878. The adopted Proper Motions result from a more general discussion, including recent observations.
† 2950. Lacaille's observations would give a very small positive Proper Motion in N.P.D.
‡ 3136. Lacaille N.P.D. disagrees with the other observations.

No.	No. in B.A.C.	Approx. R.A.	Approx. N.P.D.	Fallows R.A.	Johnson R.A.	Henderson R.A.	Cape Catalogue, 1840, R.A.	Brisbane N.P.D.	Fallows N.P.D.	Johnson N.P.D.	Henderson N.P.D.	Cape Catalogue, 1840, N.P.D.	Adopted P. Motion R.A.	Adopted P. Motion N.P.D.
		h. m.	° ′	s.	s.	s.	s.	″	″	″	″	″	s	″
171	3279	9 28	0 10					−0·11						−0·11
172	3320	9 35	150 41					−0·05				+0·04		0·00
173	3334	9 37	170 18					+0·03						+0·03
174	3353	9 41	151 51		−0·011			−0·03		−0·01		−0·04	−0·011	−0·03
175	3355	9 43	154 25	−0·001	−0·009	+0·002	+0·006	−0·06	+0·01	+0·06	+0·01	+0·04	0·000	+0·01
176	3410	9 51	143 54		−0·009		−0·005	−0·04		+0·04		+0·02	−0·007	+0·01
177	3480	10 4	171 32					−0·05				+0·05		0·00
178	3493	10 6	170 52					−0·03						−0·03
179	3509	10 8	131 25		−0·019		−0·015	−0·10		−0·02		−0·02	−0·017	−0·05
180	3516	10 10	159 20		−0·029		−0·022	−0·03		+0·01		+0·05	−0·026	+0·01
181	3526	10 12	150 38		−0·018		−0·010	−0·06		+0·02		−0·01	−0·014	−0·02
182	3536	10 14	144 19				−0·013	−0·02				+0·10	−0·013	+0·04
183	3546	10 15	145 20		−0·013			+0·02		+0·06		+0·06	−0·013	+0·05
184	3552	10 16	130 56		−0·006			−0·03		−0·02		−0·04	−0·006	−0·03
185	3578	10 20	120 21				−0·010	−0·01		+0·07			−0·010	+0·03
186	3585	10 21	163 19		−0·014		−0·003	−0·06		+0·04		+0·03	−0·008	0·00
187	3589	10 22	146 55					−0·03						−0·03
188	3594	10 22	148 1				+0·003	+0·06				0·00	+0·003	+0·03
189	3619	10 27	150 57		−0·012			−0·06		+0·10		+0·03	−0·012	+0·02
190	3644	10 31	137 29		−0·020		−0·013	0·00		+0·05		+0·03	−0·017	+0·03
191	3655	10 33	148 27				0·000	−0·14				−0·05	0·000	−0·10
192	3660	10 33	167 52		−0·012			−0·06		+0·02		+0·02	−0·012	0·00
193	3681	10 37	153 44		−0·002					+0·08		+0·02	−0·002	+0·05
194	3686	10 37	153 39	−0·008	−0·019		−0·005	0·00	+0·04	+0·04		−0·01	−0·011	+0·02
195	3695	10 39	148 56	+0·002	−0·011	−0·003	−0·002	+0·04	0·00	0·00	−0·01	+0·01	−0·003	+0·01
196	3702	10 40	138 40	+0·002	+0·004	+0·001		−0·03		+0·15	+0·11		+0·002	+0·08
197	3723	10 43	169 43					+0·11				+0·04		+0·08
198	3724	10 44	169 48		−0·040			−0·02		+0·05		−0·01	−0·040	+0·01

199	3740	10	47	148	6		−0·003		+0·004	+0·02		0·00		+0·03	0·000	+0·02
200	3803	11	0	173	50					+0·06				+0·10		+0·08
201	3866	11	14	143	43	−0·004	−0·011		0·000	−0·03	+0·03	+0·08		+0·03	−0·005	+0·03
202	3941	11	29	152	14	−0·006	−0·019		−0·005	+0·02	+0·06	+0·09		+0·08	−0·010	+0·06
203	4048	11	52	167	26		−0·019		−0·017	+0·01		+0·02		+0·03	−0·018	+0·02
204	4061	11	55	152	32				−0·025	−0·01				+0·12	−0·025	+0·06
205	4067	11	57	152	23				+0·002	+0·07				+0·03	+0·002	+0·05
206	4085	12	0	139	52				−0·011	−0·07				+0·03	−0·011	−0·02
207	4087	12	1	139	56					+0·05	+0·07	+0·09		+0·08		+0·07
208	4120	12	7	147	58	−0·006	−0·016	−0·011	−0·006	+0·05		+0·06	+0·04	+0·08	−0·010	+0·06
209	4131	12	10	168	32	−0·004	−0·032	−0·014	−0·019	+0·07		−0·08	−0·03	−0·02	−0·017	−0·02
210	4189	12	18	140	40				−0·002	+0·10				+0·11	−0·002	+0·10
211	4275	12	35	145	24				−0·004	+0·08				+0·07	−0·004	+0·07
212	4280	12	37	157	20		−0·014			+0·03		+0·02		+0·06	−0·014	+0·04
213	4289	12	39	148	55	−0·006	−0·013	−0·009	−0·007	+0·02	+0·04	+0·03	+0·02	+0·06	−0·009	+0·03
214	4293	12	40	174	21					+0·09				+0·05		+0·07
215	4313	12	44	128	55				−0·007	−0·03					−0·007	−0·03
216	4321	12	45	129	25		+0·003		−0·007	+0·05		+0·10		+0·10	−0·002	+0·08
217	4325	12	46	146	25		−0·002		+0·004	+0·12		+0·16		+0·21	+0·001	+0·16
218	4353	12	52	160	47		+0·040		+0·044	0·00		0·00		+0·02	+0·042	0·00
219	4368	12	55	138	46				−0·002	−0·02				+0·14	−0·002	+0·06
220	4379	12	58	139	9		−0·012		−0·019	−0·02		+0·07		+0·01	−0·016	+0·02
221	4409	13	3	132	37				−0·020	−0·07				−0·01	−0·020	−0·04
222	4426	13	5	157	9				−0·018	+0·01				+0·07	−0·018	+0·04
223	4460	13	14	175	5					−0·02						−0·02
224	4483	13	19	175	3					+0·01				+0·08		+0·04
225	4507	13	22	128	40		−0·012		−0·010	+0·03		+0·03		+0·05	−0·011	+0·04
226	4549	13	31	142	45	−0·015	−0·021	−0·015	−0·019	+0·02		+0·04		+0·02	−0·018	+0·02
227	4602	13	41	131	46		−0·001		+0·003	+0·01		−0·01		−0·05	+0·001	−0·02
228	4638	13	46	136	35	−0·010	−0·016	−0·009	−0·014	+0·01		+0·07	+0·07	+0·04	−0·012	+0·05
229	4660	13	51	166	7					−0·01						−0·01
230	4668	13	53	134	55				−0·010	−0·01				0·00	−0·010	0·00
231	4669	13	53	149	41	−0·008	−0·014	−0·008	−0·010	+0·01	+0·08	+0·07	+0·02	+0·07	−0·010	+0·05

No.	No. in B.A.C.	Approx. R.A.		Approx N.P.D.		Fallows R.A.	Johnson R.A.	Henderson R.A.	Cape Catalogue, 1840, R.A.	Brisbane N.P.D.	Fallows N.P.D.	Johnson N.P.D.	Henderson N.P.D.	Cape Catalogue, 1840, N.P.D.	Adopted P. Motion R.A.	Adopted P. Motion N.P.D.
		h.	m.	°	′	s.	s.	s.	s.	″	″	″	″	″	s.	″
232	4681	13	57	130	30		−0·010		−0·013	0·00		−0·03		−0·04	−0·011	−0·02
233	4705	14	4	173	1		−0·067	−0·065	−0·056	+0·02		−0·01	+0·02	+0·01	−0·063	+0·01
234	4712	14	5	169	27				−0·005	+0·02					−0·005	+0·02
235	4768	14	17	134	35				−0·004	+0·08				+0·09	−0·004	+0·09
*236	4790	14	23	177	33		−0·127	−0·170	−0·146	+0·18		+0·12	+0·05	+0·05	−0·160	+0·05
237	4811	14	26	131	32	−0·010	−0·010	−0·008	−0·008	+0·01		+0·01	−0·03	−0·02	−0·009	−0·01
238	4831	14	30	150	15		−0·486	−0·479	−0·490	−0·81		−0·74	−0·74	−0·71	−0·485	−0·75
	4832	14	30	150	15											
239	4872	14	38	146	4				−0·023	+0·23				+0·18	−0·023	+0·20
240	4883	14	40	172	28					+0·05						+0·05
241	4924	14	49	132	33		−0·018	−0·011	−0·014	+0·03		+0·07	+0·02	+0·01	−0·014	+0·03
242	4928	14	50	131	32		−0·008	+0·002	−0·002	+0·02		+0·01	−0·01	+0·01	−0·003	+0·01
243	4948	14	55	136	29		−0·009		−0·009	+0·02		+0·06		+0·05	−0·009	+0·04
244	4950	14	55	114	43					+0·06						+0·06
245	4973	14	59	134	44		−0·011			−0·07		0·00		−0·03	−0·011	−0·03
246	4986	15	2	138	12		−0·020			+0·06		+0·06		+0·06	−0·020	+0·06
247	5005	15	5	158	9	−0·012	−0·026	−0·014	−0·020	−0·04		+0·08	+0·03	+0·06	−0·018	+0·03
248	5028	15	8	137	21		−0·013		−0·018	−0·03		+0·17		+0·11	−0·015	+0·08
249	5029	15	8	137	21					+0·03				+0·09		+0·06
250	5037	15	11	173	59				+0·078	−0·07				+0·02	+0·078	−0·03
251	5046	15	12	130	8		+0·002		0·000	−0·04		−0·02		−0·03	+0·001	−0·03
252	5087	15	20	142	53					+0·01						+0·01
253	5103	15	23	155	50		−0·004		+0·001	+0·10		+0·08		+0·13	−0·002	+0·10
254	5107	15	24	165	36					+0·02				+0·07		+0·05
255	5118	15	25	130	41	−0·004	−0·006	−0·004	−0·005	0·00		+0·04	−0·02	+0·04	−0·005	+0·02
256	5121	15	26	117	34					+0·09						+0·09

* 4790. The Adopted Proper Motions have been obtained from a more general discussion, including recent observations.

257	5138	15	28	117	40					+0·08						+0·08
258	5139	15	28	132	6				−0·039	−0·09				−0·09	−0·039	−0·09
259	5144	15	29	146	27					+0·03						+0·03
260	5159	15	30	142	55					−0·07						−0·07
261	5165	15	31	134	11				−0·018	+0·24				+0·24	−0·018	+0·24
262	5200	15	38	143	57					−0·07						−0·07
263	5209	15	39	142	46				+0·013	+0·02				+0·10	+0·013	+0·06
264	5224	15	41	158	10				−0·008	+0·03				+0·04	−0·008	+0·04
*265	5233	15	42	152	59	−0·024	−0·036	−0·029	−0·020	+0·37		+0·45	+0·44	+0·47	−0·027	+0·43
266	5263	15	46	137	44					+0·01						+0·01
267	5277	15	49	143	36				+0·019	+0·08				+0·05	+0·019	+0·06
268	5292	15	50	127	59		−0·011		−0·011	+0·01		+0·10		+0·05	−0·011	+0·05
269	5320	15	56	145	48					+0·07						+0·07
270	5323	15	56	134	47					−0·07		+0·01		−0·01		−0·02
271	5339	15	59	168	20					0·00						0·00
272	5340	15	59	168	18					+0·03						+0·03
273	5374	16	2	119	2				−0·013	+0·13				+0·08	−0·013	+0·10
274	5384	16	4	147	33					+0·15						+0·15
275	5425	16	9	139	48		−0·018			+0·04		+0·07			−0·018	+0·06
276	5412	16	9	176	4		+0·022		+0·014	+0·26		−0·07			+0·018	
277	5439	16	12	168	34		−0·055		−0·036	+0·03		+0·06		+0·11	−0·045	+0·07
278	5485	16	18	147	26					+0·15						+0·15
†279	5510	16	23	167	12				−0·108	+0·31					(−0·081)	+0·31
280	5536	16	26	158	0					−0·05				+0·06		0·00
281	5538	16	27	124	57		−0·003			+0·06		0·00			−0·003	+0·03
282	5565	16	32	157	50					−0·05				+0·03		−0·01
283	5579	16	33	107	28	+0·001	+0·003					+0·06			+0·002	+0·06
284	5578	16	33	158	45	+0·006	−0·009	+0·001	+0·003	+0·04		+0·05	+0·06	+0·08	0·000	+0·06
285	5609	16	37	148	47		−0·001		0·000	+0·03		+0·01		+0·03	0·000	+0·02
286	5638	16	42	127	48		−0·009	−0·005	−0·008	+0·03		0·00	−0·01	0·00	−0·007	0·00
287	5651	16	44	132	7				+0·003	−0·05				−0·03	+0·003	−0·04

* 5233. These rather large Proper Motions are confirmed by a comparison with Lacaille's places.
† 5510. The R.A. 1840 depends upon two observations, but the recent observations indicate a Proper Motion rather smaller than 0·108.

No.	No. in B.A.C.	Approx R.A.		Approx. N.P.D.		Fallows R.A.	Johnson R.A.	Henderson R.A.	Cape Catalogue, 1840, R.A.	Brisbane N.P.D.	Fallows N.P.D.	Johnson N.P.D.	Henderson N.P.D.	Cape Catalogue, 1840, N.P.D.	Adopted P. Motion R.A.	Adopted P. Motion N.P.D.
		h.	m.	°	′	s.	s.	s.	s.	″	″	″	″	″	s.	″
288	5661	16	44	132	7				−0·020	+0·16				+0·24	−0·021	+0·20
289	5683	16	47	145	45		−0·013		−0·013	+0·12		+0·06		+0·06	−0·013	+0·08
290	5697	16	48	142	56		−0·009		−0·006	−0·08		+0·05		+0·01	−0·008	0·00
291	5713	16	51	143	1				−0·006	+0·11				+0·20	−0·006	+0·16
292	5778	17	2	133	2		−0·003	−0·004	−0·003	+0·22		+0·28	+0·27		−0·003	+0·26
293	5794	17	5	170	43				+0·011	+0·10					+0·011	+0·10
294	5803	17	6	159	58				+0·007	−0·02				+0·14	+0·007	+0·06
295	5806	17	6	149	32				+0·015	+0·12				+0·11	+0·015	+0·11
296	5836	17	10	147	51					−0·05						−0·05
297	5850	17	13	146	14	−0·004	−0·007	−0·003	0·000	−0·09		+0·04	+0·02	+0·01	−0·004	+0·01
298	5852	17	13	145	23		−0·001	0·000	+0·008	+0·09		−0·03	+0·03		+0·002	+0·03
299	5855	17	14	134	1					+0·10						+0·10
300	5859	17	15	140	30					−0·10				+0·09		0·00
301	5877	17	18	150	33					+0·13		+0·17		+0·09		+0·13
302	5899	17	21	139	45	−0·005	−0·009	−0·001	−0·005	+0·09		+0·09	+0·12	+0·11	−0·005	+0·10
303	5901	17	21	127	10		−0·009		−0·005	+0·02		+0·01		+0·09	−0·007	+0·04
304	5915	17	24	126	59		−0·010	−0·015	−0·005	+0·05		+0·03	−0·02		−0·010	+0·02
305	5930	17	26	144	24					+0·22						+0·22
306	5935	17	27	132	54	+0·002	−0·002	+0·002	+0·003	+0·08		−0·03	0·00	+0·04	+0·001	+0·02
307	5936	17	32	177	38					+0·11						+0·11
308	5970	17	32	128	57		−0·005	0·000	+0·005	+0·06		−0·01	−0·04	+0·02	0·000	+0·01
309	5974	17	33	126	52				−0·002	+0·16				+0·04	−0·002	+0·10
310	5998	17	36	145	20				+0·016	+0·03				+0·09	+0·016	+0·06
311	6004	17	37	130	4	−0·002	−0·005	−0·001	−0·002	+0·03		−0·01	−0·03	−0·13	−0·003	−0·03
312	6010	17	39	155	26					+0·05						+0·05
313	6018	17	40	126	59		−0·003		−0·004	−0·05		−0·05		−0·06	−0·003	−0·05
314	6019	17	40	130	2					+0·04				+0·07		+0·05
*315	5959	17	48	179	16	+0·228	+0·119	−0·003	+0·083			+0·02	+0·03	0·00	+0·075	+0·02

* 5959. The adopted Proper Motions have been obtained from a more general discussion, including recent observations.

316	6100	17	55	153	40				−0·009	+0·19					−0·009	+0·19
317	6105	17	55	140	5	−0·008	−0·010		−0·004	−0·04		+0·03		+0·13	−0·007	+0·04
318	6112	17	56	133	25					+0·13						+0·13
319	6148	18	2	153	5					+0·05						+0·05
320	6156	18	4	170	17					−0·01						−0·01
321	6167	18	5	146	3				+0·014	+0·08					+0·014	+0·08
322	6186	18	8	126	47		−0·018		−0·013	+0·25		+0·14		+0·15	−0·016	+0·18
323	6205	18	13	171	54					−0·03						−0·03
324	6228	18	14	134	10				−0·007	−0·05					−0·007	−0·05
325	6240	18	16	136	2		−0·017		−0·012	+0·06		+0·10		+0·04	−0·014	+0·07
326	6248	18	17	147	36					+0·04						+0·04
327	6250	18	18	139	8				+0·015	+0·23					+0·015	+0·23
328	6278	18	21	136	0	−0·002	−0·005		0·000	0·00		+0·01			−0·002	0·00
329	6291	18	23	142	59					−0·06						−0·06
330	6296	18	23	132	24		−0·028		−0·010	+0·01		+0·04			−0·019	+0·02
331	6315	18	26	161	32	−0·006	−0·009		+0·003	+0·16		+0·14		+0·10	−0·004	+0·13
332	6328	18	28	154	45				−0·005	+0·08					−0·005	+0·08
333	6352	18	31	154	59		−0·022		−0·001	0·00		+0·14		+0·16	−0·011	+0·10
334	6360	18	34	155	12				−0·007	−0·02				+0·10	−0·007	+0·04
335	6383	18	39	152	20				−0·008	+0·04				+0·04	−0·008	+0·04
336	6385	18	39	133	35				−0·007	−0·03					−0·007	−0·03
337	6405	18	42	157	24				−0·011	−0·10					−0·011	−0·10
338	6442	18	47	134	5					+0·01						+0·01
339	6443	18	47	143	7					0·00						0·00
340	6506	18	56	138	30					+0·05						+0·05
341	6511	18	56	127	15		0·000		+0·007	+0·28		+0·28		+0·30	+0·004	+0·29
342	6523	18	58	130	42		−0·002		+0·006	+0·11		+0·04		+0·05	+0·002	+0·07
343	6535	18	59	128	7		+0·005		+0·010	+0·11		+0·10		+0·11	+0·007	+0·11
344	6541	19	0	129	33		−0·011		+0·001	+0·06		+0·07			−0·005	+0·07
345	6608	19	12	134	43	−0·003	−0·006		−0·001			+0·02		+0·02	−0·003	+0·02
346	6622	19	14	130	52	−0·009	−0·004		−0·021	+0·06		+0·09			−0·011	+0·07
347	6649	19	19	145	23				−0·009	0·00					−0·009	0.00

No.	No. in B.A.C.	Approx. R.A.	Approx. N.P.D.	Fallows R.A.	Johnson R.A.	Henderson R.A.	Cape Catalogue, 1840, R.A.	Brisbane N.P.D.	Fallows N.P.D.	Johnson N.P.D.	Henderson N.P.D.	Cape Catalogue, 1840, N.P.D.	Adopted P. Motion R.A.	Adopted P. Motion N.P.D.
		h. m.	° ′	s.	s.	s.	s.	″	″	″	″	″	s.	″
348	6708	19 29	171 41					−0·04						−0·04
349	6801	19 44	163 16				+0·036	+0·13		+0·07		+0·19	+0·036	+0·13
350	6812	19 45	132 13				−0·003			−0·08			−0·003	−0·08
351	6859	19 54	173 43					+0·03						+0·03
*352	6873	19 54	156 31		+0·190			+1·17		+1·02		+1·26	+0·190	+1·15
353	6900	19 59	170 1					−0·02						−0·02
354	7004	20 14	147 10	0·000	−0·008	−0·002	−0·001	+0·07		+0·03	+0·11	+0·13	−0·003	+0·08
355	7068	20 24	166 39				+0·072	+0·15					+0·072	+0·15
356	7096	20 27	137 46	−0·001	−0·002	0·000	+0·003	−0·08		−0·11	−0·06	−0·07	0·000	−0·08
357	7106	20 29	157 14		0·000		+0·003	−0·03		+0·03			+0·001	0·00
358	7129	20 32	156 42	−0·010	−0·012	−0·007	−0·009	−0·01		−0·05	0·00	+0·06	−0·009	0·00
359	7165	20 35	159 16					−0·03						−0·03
†360	7020	20 37	179 28	−0·097	−0·200	−0·167	−0·145		+0·07	−0·01	+0·05	+0·02	−0·130	+0·01
361	7208	20 41	142 7				−0·001	+0·03					−0·001	+0·03
362	7228	20 43	148 58	−0·007	−0·008		−0·009	−0·05		−0·04		+0·06	−0·008	−0·01
363	7292	20 54	129 10				−0·008	+0·06					−0·008	+0·06
364	7314	20 57	131 56				−0·002	+0·06					−0·002	+0·06
365	7331	21 0	160 41				+0·010	−0·05					+0·010	−0·05
366	7358	21 5	148 12					+0·02						+0·02
367	7384	21 10	173 17					+0·19						+0·19
368	7409	21 14	155 59	+0·018	+0·014	+0·015	+0·028	−0·93		−0·82	−0·80	−0·78	+0·019	−0·83
369	7423	21 16	145 15		−0·005			−0·03		−0·06		−0·03	−0·005	−0·04
370	7471	21 23	131 47					+0·20						+0·20
371	7498	21 28	173 21					+0·10						+0·10
372	7538	21 34	134 7					+0·02						+0·02
373	7613	21 45	128 1	+0·004	+0·001		+0·001	+0·06		−0·02		+0·03	+0·002	+0·02

* 6873. These large Proper Motions are confirmed by a comparison with Lacaille's places.

† 7020. The adopted Proper Motions have been determined from a more general discussion, including recent observations.

374	7633	21	48	145	39		−0·005			+0·01	+0·01		0·00	−0·005	+0·01
375	7634	21	48	149	40				+0·009	−0·09				+0·009	−0·09
376	7692	21	59	137	38	+0·019	+0·009	+0·009	+0·007	+0·14	+0·10	+0·18	+0·20	+0·011	+0·15
377	7713	22	3	176	40		−0·013	−0·028	−0·030		−0·10	−0·06	−0·08	−0·029	−0·08
378	7725	22	4	171	7				+0·027	+0·07				+0·027	+0·07
379	7748	22	6	132	2				+0·051	(+0·97)	+0·75			+0·051	+0·75
380	7756	22	7	132	2		+0·001		−0·002	−0·03	−0·03			−0·001	−0·03
381	7763	22	8	132	19				−0·005	+0·11				−0·005	+0·11
382	7767	22	8	150	57	−0·002	0·011	−0·007	−0·006	0·00	+0·01	+0·07	+0·07	−0·007	+0·04
383	7808	22	17	155	40		+0·007		+0·005	−0·08	−0·04		+0·04	+0·006	−0·03
384	7828	22	20	134	12		−0·008		−0·006	+0·04	−0·02		+0·02	−0·007	+0·01
385	7830	22	21	134	27				−0·006	+0·05			+0·09	−0·006	+0·07
386	7886	22	31	172	6		−0·036	−0·036	−0·031	+0·01	−0·01	0·00	+0·02	−0·034	0·00
387	7887	22	31	140	19					+0·23					+0·23
388	7898	22	32	117	46		−0·007			(−0·17)	+0·05			−0·007	+0·05
389	7904	22	34	137	36	+0·014	+0·011	+0·008	+0·014	0·00	+0·03	+0·02	+0·09	+0·012	+0·04
390	7925	22	37	144	14				−0·004	+0·01			−0·01	−0·004	0·00
391	7946	22	40	142	3	+0·009	0·000		−0·001	+0·18	+0·03		+0·12	+0·003	+0·11
392	8008	22	52	143	30		−0·011			+0·06	−0·07			−0·011	0·00
393	8043	22	58	134	16				−0·003	+0·14			+0·07	−0·003	+0·11
394	8067	23	2	136	0	+0·010	+0·004			−0·02	+0·06			+0·007	+0·02
*395	8072	23	5	178	14		+0·100	+0·029	+0·035		−0·01	−0·01	−0·02	+0·036	−0·02
396	8093	23	8	152	45				+0·017	+0·03				+0·017	+0·03
397	8098	23	9	149	0	−0·008	−0·015		−0·013	(−0·20)	−0·04		−0·04	−0·012	−0·04
398	8157	23	17	147	37				+0·005	−0·16				+0·005	−0·16
399	8186	23	22	132	45					+0·14					+0·14
400	8201	23	25	128	35	+0·007	+0·001			−0·03	0·00			+0·004	−0·02
401	8210	23	27	133	23				−0·001	−0·05	−0·03		−0·01	−0·001	−0·03
402	8230	23	31	137	24				−0·017	−0·06	+0·04		+0·02	−0·017	0·00
403	8290	23	43	172	47		−0·031	−0·046	−0·037	−0·08	+0·02	+0·03	+0·02	−0·038	+0·02
404	8319	23	49	172	56		−0·020	−0·014	−0·019	−0·03	+0·01	+0·01		−0·018	+0·01
405	8323	23	50	155	4		+0·015			−0·04	+0·07			+0·015	+0·02
406	8334	23	52	156	21	+0·005	+0·001			−0·04	−0·02			+0·003	−0·03

* 8072. The adopted Proper Motions have been determined from a more general discussion, including recent observations.

A LIST OF PERSONS

TO WHOM

THE MEDALS OR TESTIMONIALS OF THE SOCIETY

HAVE BEEN ADJUDGED.

1823.

June 13. CHARLES BABBAGE, Esq.

The Gold Medal.—For his Invention of an Engine for computing and printing Mathematical Tables.

Professor JOHANN FRIEDRICH ENCKE.

The Gold Medal.—For his Investigations relative to the Comet which bears his name.

CHARLES RUMKER, Esq.

The Silver Medal.—For his Re-discovery of ENCKE'S Comet in 1822.

M. JEAN LOUIS PONS.

The Silver Medal.—For his Discovery of two Comets in 1822.

1826.

Feb. 7. J. F. W. HERSCHEL, Esq. and JAMES SOUTH, Esq.

The Gold Medal, each.—For their important Researches on the subject of Multiple Stars.

Feb. 10. Professor STRUVE.

The Gold Medal.—For his important Researches on the subject of Multiple Stars.

1827.

Feb. 2. FRANCIS BAILY, Esq.

The Gold Medal.—For his "New Tables for determining the places of 2,881 Stars."

WILLIAM SAMUEL STRATFORD, Esq.

The Silver Medal.—For his Superintendence of the Computation of "New Tables for determining the places of 2,881 Stars."

Feb. 5. Colonel MARK BEAUFOY.

The Silver Medal.—For his valuable Collection of Observations, particularly those of the Eclipses of *Jupiter's* Satellites.

1828.

Jan. 11. Sir THOMAS MACDOUGALL BRISBANE, K.C.B.

The Gold Medal.—For his Establishment of an Observatory, and for an important series of Observations made at Paramatta.

JAMES DUNLOP, Esq.

The Gold Medal.—For his Observations of the Nebulæ of the Southern Hemisphere.

Feb. 4. Miss CAROLINE HERSCHEL.

The Gold Medal.—For her recent reduction, to January 1800, of the Nebulæ discovered by Sir WILLIAM HERSCHEL.

1829.

Jan. 9. Rev. WILLIAM PEARSON.

The Gold Medal.—For his work entitled "An Introduction to Practical Astronomy."

Professor BESSEL.

The Gold Medal.—For his Zone Observations.

Professor SCHUMACHER.

The Gold Medal.—For the Publication of his various Astronomical Tables, and the "Astronomische Nachrichten."

1830.

Jan. 8. Mr. WILLIAM RICHARDSON.

The Gold Medal.—For his Investigation of the Constant of Aberration.

Professor ENCKE.

The Gold Medal.—For the New Berlin Ephemeris.

1831.

Jan. 14. Captain KATER.

The Gold Medal.—For his Invention of the Vertical Floating Collimator.

Baron DAMOISEAU.

The Gold Medal.—For his Memoir upon the Theory of the Moon, and for his Lunar Tables.

1833.

Jan. 11. Professor AIRY.

The Gold Medal.—For his Discovery of the long Inequality of *Venus* and the Earth.

1835.

Jan. 9. Lieutenant JOHNSON.

The Gold Medal.—For his Catalogue of 606 Southern Stars.

1836.

Jan. 8. Sir JOHN F. W. HERSCHEL.

The Gold Medal.—For his Catalogue of Nebulæ, printed in the "Philosophical Transactions" for 1833.

1837.
Jan. 13. Professor Rosenberger.
The Gold Medal.—For his Investigations relative to Halley's Comet.

1839.
Jan. 11. Hon. John Wrottesley.
The Gold Medal.—For his Catalogue of the Right Ascensions of 1,318 Stars.

1840.
Jan. 10. M. Jean Plana.
The Gold Medal.—For his Work, entitled "Théorie du Mouvement de la Lune."

1841.
Jan. 8. Professor Bessel.
The Gold Medal.—For his Observations and Researches on the Parallax of 61 *Cygni.*

1842.
Jan. 14. M. Hansen.
The Gold Medal.—For his Researches in Physical Astronomy.

1843.
Jan. 13. Francis Baily, Esq.
The Gold Medal.—For his Experiments to determine the Mean Density of the Earth in repetition of what is generally termed the "Cavendish Experiment."

1845.
Jan. 10. Captain William Henry Smyth, R.N.
The Gold Medal.—For his "Bedford Catalogue," forming the second part of his work entitled "Celestial Cycle."

1846.
Jan. 9. George Biddell Airy, Esq., Astronomer Royal.
The Gold Medal.—For his Reduction of the Observations of Planets made at the Royal Observatory, Greenwich, from 1750 to 1830.

1848.
Jan. 14. *Testimonials were awarded to*

George Biddell Airy, Esq., Astronomer Royal.
For the Lunar Reductions recently made at Greenwich.

John Couch Adams, Esq.
For his Researches in the Problem of Inverse Perturbations leading to the Discovery of the Planet *Neptune.*

Professor Argelander.
For his Catalogue of Stars.

1848.

Jan. 14. GEORGE BISHOP, Esq.

For the Foundation of an Observatory leading to various Astronomical Discoveries.

Lieut.-Col. GEORGE EVEREST.

For his Measurement of the Indian Arc.

Sir JOHN F. W. HERSCHEL.

For his Work on the Southern Hemisphere.

Professor P. A. HANSEN.

For his Lunar Theory and Computation of Perturbations.

M. HENCKE.

For his Discovery of Two Planets, *Astræa* and *Hebe*.

JOHN RUSSELL HIND, Esq.

For his Discovery of two Planets, *Iris* and *Flora*.

M. U. J. LE VERRIER.

For his Researches in the Problem of Inverse Perturbations leading to the Discovery of the Planet *Neptune*.

Sir JOHN LUBBOCK.

For his Researches in the Theory of Perturbations.

M. M. WEISSE.

For his Catalogue of Stars in BESSEL'S Zones.

1849.

Feb. 9. WILLIAM LASSELL, Esq.

The Gold Medal.—For the Construction of his Equatoreal Instrument and for the Discoveries made with it.

1850.

Feb. 8. M. OTTO VON STRUVE.

The Gold Medal.—For his Paper on the Constant of Precession.

1851.

Feb. 15. Dr. ANNIBALE DE GASPARIS.

The Gold Medal.—For the Discovery of three Planets, *Hygeia*, *Parthenope*, and *Egeria*.

1852.
Feb. 13. Dr. C. A. F. PETERS.
The Gold Medal.—For his Papers on the Parallax of the Fixed Stars, and on the Constant of Nutation.

1853.
Feb. 11. JOHN RUSSELL HIND, Esq.
The Gold Medal.—For the Discovery of eight Planets, and other Astronomical Discoveries.

1854.
Feb. 10. M. CHARLES RUMKER.
The Gold Medal.—For his Catalogue of 12,000 Stars, and for other Astronomical Services.

1855.
Feb. 9. Rev. W. R. DAWES.
The Gold Medal.—For his Astronomical Labours generally.

1856.
Feb. 8. ROBERT GRANT, Esq., M.A.
The Gold Medal.—For his "History of Physical Astronomy."

1857.
Feb. 13. M. SCHWABE.
The Gold Medal.—For his Discovery of the Periodicity of the Solar Spots.

1858.
Feb. 12. Rev. ROBERT MAIN, M.A.
The Gold Medal.—For his various Contributions to the *Memoirs* of the Society.

1859.
Feb. 11. R. C. CARRINGTON, Esq.
The Gold Medal.—For his "Redhill Catalogue of 3,735 Circumpolar Stars."

1860.
Feb. 10. Professor P. A. HANSEN.
The Gold Medal.—For his Lunar Tables.

1861.
Feb. 8. M. HERMANN GOLDSCHMIDT.
The Gold Medal.—For his Discovery of thirteen of the Minor Planets, and other Astronomical Discoveries.

1862.
Feb. 14. WARREN DE LA RUE, Esq.
The Gold Medal.—For his Astronomical Researches, and especially for his Application of Photography.

1863.
Feb. 13. Professor ARGELANDER.
The Gold Medal.—For his Survey of the Northern Heavens.

1865.
Feb. 10. Professor G. P. BOND.
The Gold Medal.—For his work on the Comet of DONATI, and other Astronomical Researches.

1866.
Feb. 9. Professor ADAMS.
The Gold Medal.—For his Contributions to the Development of the Lunar Theory.

1867.
Feb. 8. W. HUGGINS, Esq. and Professor MILLER.
The Gold Medal.—For their Researches in Astronomical Physics.

1868.
Feb. 14. M. LEVERRIER.
The Gold Medal.—For his Planetary Tables.

1869.
Feb. 12. E. J. STONE, Esq.
The Gold Medal.—For his Rediscussion of the Transit of *Venus* in 1769, and his other contributions to Astronomy.

1870.
Feb. 11. M. DELAUNAY.
The Gold Medal.—For his "Théorie de la Lune."

1872.
Feb. 9. Signor SCHIAPARELLI.
The Gold Medal.—For his Researches on the Connexion between the Orbits of Comets and Meteors.

1874.
Feb. 13. Professor SIMON NEWCOMB.
The Gold Medal.—For his Tables of *Neptune* and *Uranus*, and other contributions to Mathematical Astronomy.

1875.
Feb. 12. Professor D'ARREST.
The Gold Medal.—For his work entitled "Siderum Nebulosorum Observationes Havnienses, institutæ in Specula Universitatis per tubum sedecimpedalem Merzianum, ab anno 1861 ad annum 1867," and other Astronomical Works.